

THE BRITISH SOCIETY FOR THE PROMOTION
OF VEGETABLE RESEARCH

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Eleventh
Annual Report
1960

(OCT. 1959 - SEPT. 1960)

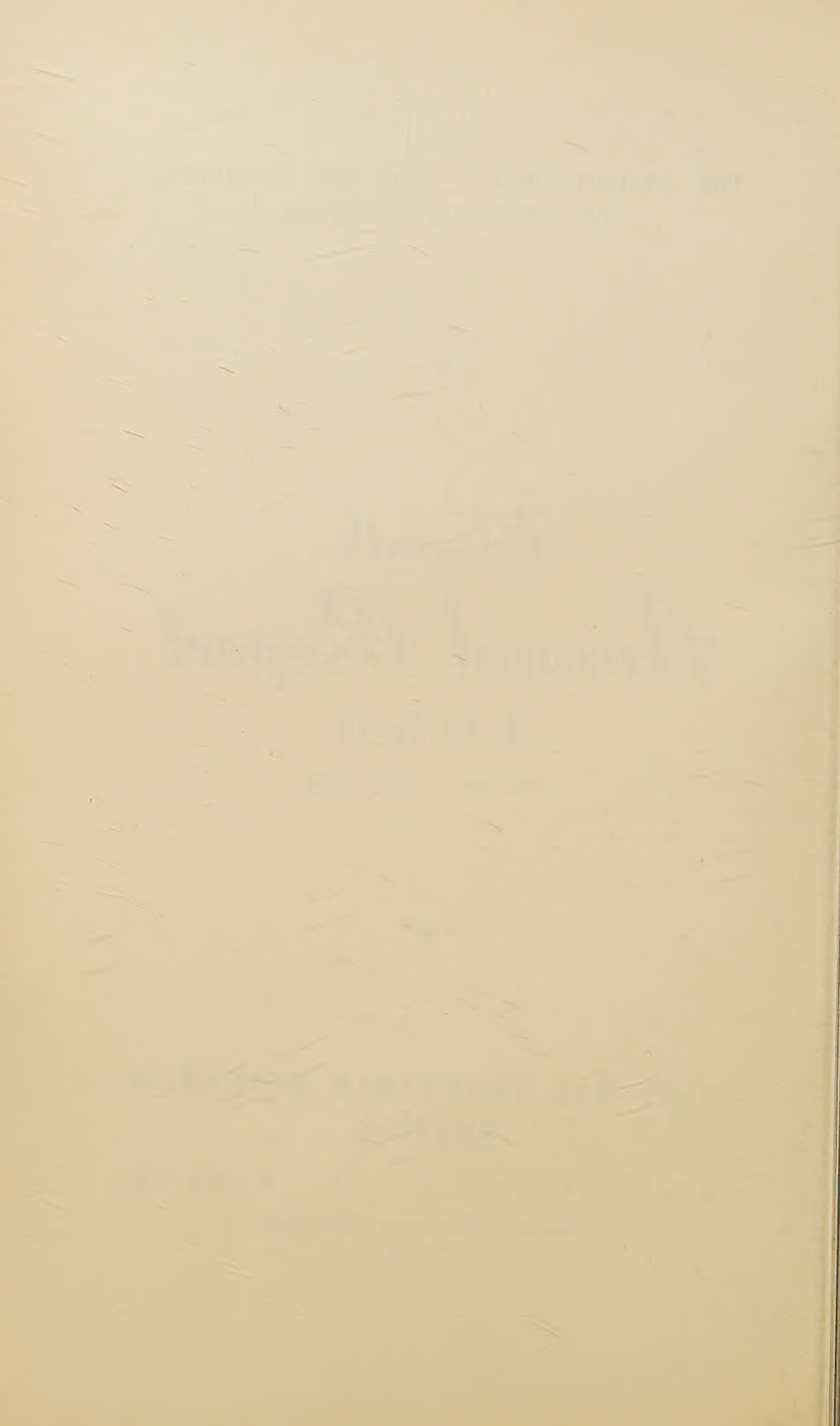
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NATIONAL VEGETABLE RESEARCH
STATION

WELLESBOURNE - - WARWICK

Telephone : Wellesbourne 382 (3 lines)

1961



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THE CONSTITUTION OF THE NATIONAL VEGETABLE RESEARCH STATION

The National Vegetable Research Station (N.V.R.S.) at Wellesbourne, Warwickshire, and its Sub-Station at Paglesham, Essex, were established under a Governing Body incorporated on 28th September 1949, as a company limited by guarantee, not having a share capital, and having the title 'The British Society for the Promotion of Vegetable Research', with its registered office at Wellesbourne.

The members of the Governing Body, twenty-three in number, include nominees of the Lord President of the Council and of the two Agricultural Departments of Great Britain, of the Department of Scientific and Industrial Research, of various learned societies, universities and institutions concerned with horticulture, of vegetable producers (through the National Farmers' Unions of the two countries and the National Allotments and Gardens Society) and of trade interests.

The properties at Wellesbourne and Paglesham are leased to the Society by the Agricultural Research Council (A.R.C.). Until 31st March 1956, the Society depended for its funds on grants from the Ministry of Agriculture, Fisheries and Food who were advised by the A.R.C. regarding research work and staff. On 1st April 1956, the grant-aiding functions of the Ministry were transferred to the A.R.C.

GOVERNING MEMBERS OF THE SOCIETY

Appointed by the Lord President of the Council, the Minister of Agriculture, Fisheries and Food, and the Secretary of State for Scotland:

Professor K. MATHER, C.B.E., D.Sc., F.R.S., Department of Genetics,
The University, Edgbaston, Birmingham, 15.

W. J. F. SOPER, Esq., J.P., New Hall Farm, Harlow, Essex.

Professor M. STACEY, Ph.D., D.Sc., F.R.S., Department of Chemistry,
The University, Edgbaston, Birmingham, 15. (From 28/9/1960).

Professor P. T. THOMAS, B.Sc., Ph.D., Department of Agricultural Botany,
The Institute of Rural Science, University College of Wales,
Penglais, Aberystwyth. (Until 27/9/1960).

Principal M. A. H. TINCKER, M.A., D.Sc., F.C.S., F.R.S.E., F.L.S.,
The North of Scotland College of Agriculture, 41½ Union Street, Aberdeen.

Professor C. W. WARDLAW, M.Sc., Ph.D., D.Sc., D.Sc. (McGill), F.R.S.E., F.L.S.,
Department of Botany, The University, Manchester, 13.

Appointed by the Department of Scientific and Industrial Research:

R. G. TOMKINS, Esq., M.A., Ph.D., Ditton Laboratory, Larkfield, Maidstone, Kent.

Appointed by the University of London:

Professor H. W. MILES, Ph.D., D.Sc., Wye College, (University of London), Ashford, Kent.

Appointed by the University of Reading:

Professor O. V. S. HEATH, D.Sc., F.R.S.,
Department of Horticulture, The University, Reading, Berks.

Appointed by the University of Cambridge:

J. BARKER, Esq., M.A., Ph.D., F.R.S., The Botany School, Downing Street, Cambridge.

Appointed by the University of Bristol:

Professor H. G. H. KEARNS, O.B.E., B.Sc., Ph.D., Dip. Agric., University of Bristol,
Department of Agriculture and Horticulture, Research Station, Long Ashton,
Bristol.

Appointed by the University of Edinburgh:

ALEXANDER NELSON, Esq., Ph.D., D.Sc., F.R.S.E.,
University Department of Botany, at Royal Botanic Garden, Edinburgh, 3.

Appointed by the Royal Society:

Professor W. BROWN, M.A., D.Sc., F.R.S., The Bush, Haddenham, Aylesbury, Bucks.

Appointed by the John Innes Institute:

K. S. DODDS, Esq., Ph.D., D.Sc., Bayfordbury, Herts.

Appointed by the National Farmers' Union:

F. M. BARDSLEY, Esq., Low Mill Farm, East Ayton, Scarborough, Yorks.

R. FORD, Esq., Began Farm, St. Mellons, Cardiff, Glamorgan.

G. G. HOLE, Esq., Pakyns, Hurstpierpoint, Sussex.

J. LAITY, Esq., Polkinghorne, Gwinear, Hayle, Cornwall.

W. F. SWIFT, Esq., Avon Cottage, Fladbury, Pershore, Worcs.

Appointed by the National Farmers' Union of Scotland:

DAVID LOWE, Esq., C.B.E., F.R.S.E., Elvingston, Gladsmuir, East Lothian. (Chairman).

Appointed by the Horticultural Trades' Association:

J. S. W. CRACKNELL, Esq., O.B.E., V.M.H., 'Glenhurst', Arbor Lane, Winnersh,
Wokingham, Berks.

Appointed by the Royal Horticultural Society:

Professor T. WALLACE, C.B.E., M.C., D.Sc., F.R.I.C., V.M.H., F.R.S.,
'Redwings', Old Church Road, Nailsea, Somerset.

Appointed by the National Allotments and Gardens Society:

Professor J. CALDWELL, Ph.D., D.Sc., Hatherly Biological Laboratories,
Prince of Wales Road, Exeter.

Appointed by the Seed Trade Association of the United Kingdom:

F. HOLL, Esq., Harrison and Sons (Leicester) Ltd., St. James' Street, Leicester.

The Executive Committee

Professor W. BROWN
J. S. W. CRACKNELL, Esq.
Professor O. V. S. HEATH
G. G. HOLE, Esq.
J. LAITY, Esq.

DAVID LOWE, Esq.
Professor K. MATHER
W. F. SWIFT, Esq.
Professor T. WALLACE (Chairman)
Professor C. W. WARDLAW

Staff and Research Sub-Committee

Professor W. BROWN (Chairman)
J. S. W. CRACKNELL, Esq.
R. FORD, Esq.
Professor O. V. S. HEATH
Professor H. G. H. KEARNS

DAVID LOWE, Esq.
Professor K. MATHER
W. J. F. SOPER, Esq.
Dr. R. G. TOMKINS
Professor T. WALLACE

Co-opted:

C. E. HUDSON, Esq., C.B.E., N.D.H., V.M.H., Ministry of Agriculture, Fisheries and Food,
Great Westminster House, Horseferry Road, London, S.W.1.

Farm Management Sub-Committee

F. M. BARDSLEY, Esq.
G. G. HOLE, Esq.
F. HOLL, Esq.

J. LAITY, Esq.
W. J. F. SOPER, Esq.
W. F. SWIFT, Esq. (Chairman)

Co-opted:

F. H. VANSTONE, Esq., B.Sc., Ph.D., A.Inst.P., Head of Horticultural Engineering
Department, National Institute of Agricultural Engineering, Wrest Park, Silsoe, Beds.

Varieties Inspection Sub-Committee

J. S. W. CRACKNELL, Esq.
DAVID LOWE, Esq. (Chairman)
G. G. HOLE, Esq.

F. HOLL, Esq.
W. F. SWIFT, Esq.

Co-opted:

C. D. R. DAWSON, Esq., Ph.D., A. L. Tozer Ltd., Pyports, Cobham, Surrey.
F. G. POTTER, Esq., Sutton and Sons Ltd., The Royal Seed Establishment, Reading, Berks.
L. A. W. PRIOR, Esq., W. Deal and Sons Ltd., Kelvedon, Essex.

STAFF

Director:

JAMES PHILP, B.Sc. (Glas.), Ph.D. (Lond.).*

Deputy Director:

D. W. WRIGHT, M.A. (Cantab.).*

Plant Breeding: J. C. HAIGH, B.Sc., Ph.D. (Lond.), A.R.C.S., A.I.C.T.A.

H. HOLLAND, B.Sc. (Wales).

A. G. JOHNSON, B.Sc. (Lond.), Ph.D. (Wales).

L. E. WATTS, B.Sc. (Wales).

G. J. FAULKNER.

G. J. FROST, B.Sc. (Dunelm).

R. A. T. GEORGE.

Miss E. M. SLADE, B.Sc. (Bristol).

Assistants: Miss D. E. ALLEN.

Mrs. J. M. H. AUSTIN.

Miss S. R. C. CHURCHILL.

Mrs. P. A. DILLON (née DYMOND).

Miss G. DRAYCOTT. (Appointed 26/10/1959)

Miss P. M. MILLS. (Appointed 29/2/1960)

I. MITCHELL. (Resigned 30/9/1960)

Miss P. NORMAN. (Appointed 5/9/1960)

B. WOODWARD. (Resigned 31/7/1960)

Chemistry:

F. HAWORTH, B.Sc., Ph.D. (Liverpool), Dip. Ag. Sci. (Cantab.).

S. P. SPRAGG, B.Sc., Ph.D. (Bristol). (Resigned 30/9/1960)

D. J. GREENWOOD, B.Sc. (Liverpool), Ph. D. (Aberdeen).

T. J. CLEAVER.

Miss P. M. LIEVESLEY, B.Sc. (Bristol).

Assistants: Miss M. A. BENNETT.

Miss P. CHANDLER.

M. J. CLAYTON.

D. GOODMAN.

Miss M. J. JONES. (Appointed 20/6/1960)

Miss D. MOORE. (Appointed 15/2/1960)

Physiology:

E. J. WINTER, M.C., M.Sc. (Bristol).

J. K. A. BLEASDALE, B.Sc., Ph.D. (Manc.).

R. B. AUSTIN, B.Sc. (Birm.).

R. THOMPSON, B.Sc. (Lond.).

Assistants: Miss C. J. BRUTON. (Appointed 1/10/1960)

Mrs. I. H. FROST.

B. G. HUNT.

Mrs. J. I. E. MITCHELL.

Miss S. SMITH. (Resigned 21/9/1960)

Irrigation:

E. J. WINTER, M.C., M.Sc. (Bristol).

P. J. SALTER, M.Sc. Hort., Ph.D. (Nott.).

D. H. DREW, B.Sc. (Lond.).

P. J. M. SALE, B.Sc., Ph.D. (Reading).

Miss F. L. C. BLACKWALL, B.Sc. Hort. (Lond.), Dip. Hort. (Studley).

J. B. WILLIAMS, B.Sc. (Sheffield).

Assistants: Miss J. BANNAN.

Miss C. DOWN.

Miss S. J. HEMMINGS.

R. JOBSON. (Appointed 1/9/1960)

G. M. R. TRUEMAN. (Resigned 30/4/1960)

Miss K. VINCENT.

*Recognised lecturer of the University of Birmingham.

- Entomology:** D. W. WRIGHT, M.A. (Cantab.).*
 J. A. DUNN, M.Sc. (Dunelm), Ph.D. (Birm.).
 T. H. COAKER, B.Sc. (Lond.), A.R.C.S., D.I.C.
 G. A. WHEATLEY, B.Sc. (Dunelm).
 J. A. HARDMAN, B.Sc. Hort. (Nott.).
 Miss J. KIRKLEY, B.A. (Cantab.). (Appointed 5/9/1960)
 Mrs. D. D. SALTER, B.Sc. (Dunelm). (Resigned 31/1/1960)
 Miss J. WORRALL, B.Sc. (Lond.). (Resigned 30/6/1960)
Assistants: H. I. SMITH.
 Miss C. M. LOWE.
 Mrs. G. D. MAUDE (née BUBB).
 K. NIENDORF.
 Mrs. J. SELWYN.
 Miss J. TILSLEY.
- Pathology:** W. G. KEYWORTH, B.Sc., Ph.D. (Lond.), A.R.C.S., D.I.C.*
 A. G. CHANNON, B.Sc. (Aberdeen), Ph.D. (Birm.).
 R. B. MAUDE, B.A. (Dublin), M.Sc. (Nott.).
 J. A. TOMLINSON, B.Sc., Ph.D. (Birm.).
 Miss J. BRITTON, B.Sc. (Lond.). (Appointed 12/9/1960)
 R. G. GARRETT, B.Sc. (Lond.). (Appointed 19/9/1960).
 Miss R. P. GOODCHILD, B.Sc. (Leeds). (Resigned 30/6/1960)
 R. A. L. HINTON, B.Sc. (Reading). (Appointed 8/8/1960)
 Miss J. S. HOWELL, B.Sc. (Birm.). (Resigned 7/3/1960)
 Miss B. R. SMITH, B.Sc. Hort. (Lond.). (Resigned 31/8/1960)
 M. J. W. WEBB, B.Sc. Hort. (Nott.).
Assistants: Mrs. G. A. DAYES.
 Miss J. M. DOW.
 Miss M. P. INSALL.
 Miss H. O'MAHONEY. (Appointed 12/9/1960)
 Miss E. M. SISSON. (Appointed 8/8/1960)
 Mrs. J. STALLARD (née TAYLOR). (Resigned 31/7/1960)
- Weeds:** H. A. ROBERTS, B.Sc. (Manc.).
 J. M. WAY, B.Sc. Hort., M.Sc. (Lond.). (Working under A.R.C. grant)
 Miss S. M. S. HIRD, B.Sc. (Lond.), M.Sc. (Saskatchewan).
 Bernard J. WILSON, B.Sc. Agric. (Reading).
Assistants: Mrs. A. H. T. GEORGE.
 Mrs. U. W. GIBBS (née LAURENCE)
 Miss C. A. LEADBEATER, Dip. Hort. (Studley).
 (Working under A.R.C. grant)
 Brian J. WILSON.
- Statistics:** J. A. NELDER, M.A. (Cantab.).*
 Miss L. A. KEMP, B.Sc. (Lond.).
 Miss K. M. WILSON, B.Sc. (Reading). (Resigned 5/8/1960)
Assistants: Miss A. DRAYCOTT.
 Miss H. E. RUSSELL.
 Miss A. R. TUFFIN. (Resigned 31/7/1960)
- Librarian:** D. A. WOODROFFE, B.Sc. (Nott.). (Appointed 28/3/1960)
- Photographer:** R. H. MOCKFORD.
- Farm:** *Manager:* T. J. NORWOOD.
Wellesbourne—Senior Farm Assistant: W. G. BROWN, N.D.A., N.D.D.
Senior Glasshouse Assistant: J. G. J. McGHEE, S.D.H.
Paglesham Foreman: D. T. McVITTIE.
- Administration:** *Secretary* - - - G. LESSON, B.Sc. (Econ.), A.C.I.S.
Accounts Assistant - - - D. A. BARTLETT.
Administrative Assistant - - L. C. FITZGERALD.
Director's Secretary - - Mrs. J. M. FAULKNER.
Clerical Officers - - - Miss S. CLARKE.
 Miss D. LONG.
Assistants: Miss G. E. A. CLACK. (Resigned 25/6/1960)
 Miss L. L. JOHNSON. (Appointed 27/6/1960)
 Miss S. M. L. McDONAUGH.
 Miss B. M. NUTTER, M.A. (Edin.). (Appointed 11/7/1960)
 Miss J. SHAW. (Resigned 6/7/1960)

*Recognised lecturer of the University of Birmingham.

REPORT OF THE DIRECTOR

Since the inception of the Station 11 years ago, 1960 was the first year during which no building development took place. Three of the temporary wooden laboratories which were used prior to the completion of the new laboratory building, however, were dismantled and the material used to provide four field huts at vantage points on the Station and one field hut at the Sub-Station at Paglesham.

STAFF

Appointments

On 28th March 1960 Mr. D. A. Woodroffe was appointed as Librarian in succession to Miss B. M. Moore.

Mr. R. A. L. Hinton was appointed as an Assistant Experimental Officer on 8th August 1960 in the Pathology Section.

On 5th September 1960 Miss J. Kirkley was appointed as an Assistant Experimental Officer in the Entomology Section.

Miss J. Britton was appointed on 12th September 1960 as an Assistant Experimental Officer in the Pathology Section.

Mr. R. G. Garrett joined the staff as an Assistant Experimental Officer in the Pathology Section on 19th September 1960.

The following nine Scientific Assistants were appointed during the year, six of whom replaced those who had left:—

Miss C. J. Bruton, Physiology
Miss G. Draycott, Plant Breeding
Mr. R. Jobson, Irrigation
Miss M. J. Jones, Chemistry
Miss P. M. Mills, Plant Breeding

Miss D. Moore, Chemistry
Miss P. Norman, Plant Breeding
Miss H. O'Mahoney, Pathology
Miss E. M. Sisson, Pathology

Nine University students were employed during the summer to assist in the research sections.

Miss L. L. Johnson was appointed as a Copy-Typist on 20th June, and Miss B. M. Nutter was appointed as a Shorthand-Typist on 11th July 1960.

Resignations

Dr. S. P. Spragg resigned on 30th September 1960 to take up a research fellowship in the Chemistry Department of the University of Birmingham.

Mrs. D. D. Salter resigned on 31st January 1960.

Miss J. S. Howell resigned on 7th March 1960 prior to her marriage.

Miss R. P. Goodchild and Miss J. Worrall resigned on 30th June 1960.

Miss K. M. Wilson resigned on 5th August 1960.

Miss B. R. Smith resigned on 31st August 1960.

Six Scientific Assistants resigned during the year;

Mrs. J. Stallard and Mr. B. Woodward took up positions elsewhere;

Mr. G. M. R. Trueman joined the R.A.F. and Miss A. R. Tuffin joined the W.R.N.S.; Mr. I. Mitchell and Miss S. Smith resigned on gaining entrance to Universities.

Miss G. E. A. Clack left the Station on 25th June and Miss J. Shaw resigned on 6th July 1960.

Higher degree

We congratulate Mr. A. G. Channon on having been awarded the degree of Ph.D. by the University of Birmingham for his thesis entitled 'Studies on parsnip canker' which was based on work carried out by him at Wellesbourne.

Secondment from the A.R.C. Weed Research Organisation

At the request of Dr. E. K. Woodford, Director of the A.R.C. Weed Research Organisation, Oxford, we were pleased to provide accommodation for a member of his staff, Dr. G. W. Ivens, in the Weeds Section at the N.V.R.S. as from 26th October 1959 until additional accommodation became available at their new centre at Kidlington, Oxford, on 1st September 1960. While at Wellesbourne, Dr. Ivens was engaged in planning experiments on weed control in fruit and flower crops and he also co-operated with the Weeds Section in work on the persistence of residual herbicides in soil.

Conferences in the U.K. and abroad

Members of the research staff attended a number of conferences during the year. In October 1959 Mr. Roberts read a paper on 'Weed control in vegetable crops' at the East Midlands Horticultural Conference at Sutton Bonington. Mr. Wheatley and Mr. Hardman attended the Association of Applied Biologists' (A.A.B.) meeting in London in December, when Mr. Wheatley contributed a paper on 'Bioassay of residues of insecticides in soil'. Also in December, Dr. Haworth gave a talk on 'Fertiliser responses of some vegetable crops' to members of the Society of Chemical Industry (Agricultural Group) in London. At the joint meeting of the A.A.B. and the British Mycological Society held in London in January 1960, Dr. Haigh read a paper on 'Breeding disease-resistant vegetables'. Mr. Austin and Dr. Bleasdale attended the A.A.B. meeting on aspects of crop physiology in London in February. The A.R.C. Insecticide and Fungicide Conference held at East Malling at the end of March was attended by Mr. Wright and Dr. Dunn. In April, Dr. Greenwood attended the British Society of Soil Science meeting in Edinburgh, when he read a paper on 'The effect of oxygen concentration on some soil microbial processes'. In April also, Mr. Austin and Dr. Bleasdale attended the Society for Experimental Biology symposium at Nottingham, and Mr. Roberts and Mr. Wilson were present at the British Weed Control Conference at Oxford, where Mr. Roberts gave a paper entitled 'Herbicides and the soil'. At the East Anglian Regional Conference for Further Education at Cambridge in June, Mr. Wright contributed a paper on 'Pest control in vegetable crops'. Mr. Wright was a delegate at the VII Commonwealth Entomological Conference in London in July, and in that month Dr. Greenwood and Dr. Spragg attended the Biochemical Society meeting in Bristol. Mr. Wright attended the British Association meeting in Cardiff in September and gave a paper on 'The control of the cabbage root fly'. At the Horticultural Education Association's Annual Autumn Conference held at Bristol in September, Mr. Roberts contributed a paper on 'Herbicides for vegetable crops'. In that month also, Dr. Bleasdale attended the Society for Experimental Biology symposium on 'Mechanism of competition' at Southampton, and Mr. Roberts gave a paper on 'Chemical weed control in vegetable crops' at the Hertfordshire Institute of Agriculture Fifth Horticultural Refresher Course at St. Albans. Mr. Wheatley read a paper on 'Some properties used in insecticides' at the London symposium on powders in industry.

A grant was kindly provided by the A.R.C. to enable Mr. Holland to visit research stations and seed firms in Holland, Germany, Sweden and Denmark between 20th June and 12th July. The A.R.C. also provided grants to enable members of staff to attend the following conferences. Mr. Wright and Mr. Wheatley attended the XI International Congress of Entomology in Vienna during August, when Mr. Wright read a paper on 'Factors to be considered in the development of methods for the control of the carrot fly'. In August also, Dr. Haworth attended the Seventh International Congress of Soil Science at Madison, U.S.A., after which he visited various research stations in that country. Dr. Haigh joined the EUCARPIA Working Group on Asparagus in Hanover in September.

Lectures

About 20 lectures on various aspects of the Station's research work were given by

members of staff to growers and officers of the N.A.A.S., etc., in different parts of the country during the year.

Mr. Nelder gave a course of 25 lectures to post-graduate students at the University of Birmingham on 'The design and analysis of experiments'. In November 1959 Mr. Wright gave two lectures to final honours students of the Zoology Department of the University of Birmingham on 'The biology, ecology and control of certain insects of economic importance'.

Television

On 26th June 1960, in the B.B.C. T.V. weekly series entitled 'Farming', Mr. Winter talked about the irrigation of vegetables and gave a commentary on a film showing irrigation experiments and equipment at the N.V.R.S. and the Luddington E.H.S.

Exhibit

The Irrigation Section staged an exhibit in the Scientific Section at the Royal Horticultural Society's Chelsea Show in London in May 1960, illustrating the irrigation of vegetables. The Section also staged a similar exhibit at the Royal Leamington Spa Horticultural Society's show on 8th-10th September.

Sporting and social activities

On 4th January 1960, members of the Station joined with the choir of St. Peter's Church, Wellesbourne, in singing carols under the direction of Mr. Faulkner who also played the church organ.

Once again an excellent meal was prepared for the staff Christmas lunch on 7th January and was greatly appreciated by the 90 people present. For this, our grateful thanks go to the Canteen Committee and to the kitchen staff. The Christmas-New Year Party was held in the Lecture Room on 15th January and 122 people were entertained on this enjoyable occasion. An informal dance was held in the Lecture Room on 1st April and was much enjoyed by the 92 people present. Following the successful formal dances held in previous years, the Sports and Social Committee arranged a buffet-dance at the Ettington Park Hotel on 6th May, when a pleasant evening's dancing in an old-world atmosphere was enjoyed by 58 people. Our thanks are due to Dr. Bleasdale (Chairman), Mrs. Dayes, Miss Goodchild (until 19/6/60), Dr. Greenwood (Acting Secretary from 29/6/60), Miss Leadbeater (from 21/6/60), Mr. McGhee (from 21/6/60), Mr. Thompson (Treasurer), Miss Wilson (Secretary until 28/6/60), and Miss Worrall (until 14/6/60), who comprised the Sports and Social Committee, for organising the three events, and to all those members of staff who helped towards the success of these functions.

The Stamp Club continued to meet during the winter months and was privileged once again to hear a talk by Mr. J. S. W. Cracknell and to see part of his specialised collection of stamps of India. The mixed hockey team won three of its six matches. The lawn tennis team played eleven matches during the season and won two, the majority of the others being lost by narrow margins. The table tennis club continued to hold well-supported meetings and won both of its matches. The cricket team played nine matches of which they won three, lost five and drew one.

We were pleased to welcome the Long Ashton Research Station cricket and tennis teams, and supporters to the Station on 2nd July when the N.V.R.S. succeeded in winning both matches. Besides those taking part in the sports, some 60 people enjoyed the pleasant afternoon, and rounded it off by taking tea in the canteen and on the lawns.

RESEARCH

Plant Breeding

Fourth generation families of lettuce which are immune from downy mildew and are of the butterhead type have been bred from an American crisp type possessing this

immunity. Work is continuing also in an attempt to transfer the characteristic of non-transmission of mosaic virus through seed, from the winter glasshouse variety Cheshunt Early Giant, to summer lettuce.

Initial tests of a method for the production of hybrid Brussels sprout seed on a commercial scale have given promising results. Pollination was done by insects in nylon cages in the field and male sterile or brother-sister incompatible inbred lines were used. Some of the hybrids from seed produced in this manner gave much improved yields of marketable sprouts over those of comparable varieties.

The excessive bolting of spring cabbage during the 1959-60 season showed that previous selection against this character in breeding material had been very successful, and permitted further rigid selection to be made. In consequence, the types being developed to give early crops of partially hearted spring greens are likely to have low bolting propensities.

The mild winter of 1959-60, in contrast to previous winters, provided little natural selection for winter hardiness among hybrid derivatives, up to the fifth generation, of crosses between the maple pea and commercial wrinkled varieties of peas. Small scale tests indicated that some families matured as early as, or earlier than the earliest spring sown variety and were equal to, or better than the variety Dark-Skinned Perfection regarding flavour, colour and yield of peas.

The high resistance to *Didymella* stem rot disease of outdoor tomatoes found in hybrids between a strain of *Lycopersicon hirsutum* and a cultivated tomato variety, appears to be controlled by polygenes and is thus making difficult the breeding of a cultivated type having resistance.

Breeding work was continued with red beet, onions, parsnips, winter cabbage, cauliflowers, asparagus and celery.

Supplies of nuclear stock seed of those Cambridge varieties which are already on the market were again provided to the N.I.A.B. for stock seed production. The stock seed will be supplied to recognised seed growers for the production of commercial seed under the scheme described in the Annual Report for 1952.

Chemistry

In 1960, when the third cycle of the three year crop rotation of vegetables began in the three long-term field experiments, changes were made in some treatments and crops so that measurements could be made of the residual effects of farmyard manure and of the effects of increased rates of application of fertilisers, and studies could be extended to a wider range of vegetable crops. During the first year the residual effect on yield of six years' application of FYM, as compared with the effect of the seventh year of application of FYM, was about 7 per cent less with autumn lettuce, about equal with summer cauliflower, and about 10 per cent better with peas.

Experiments with leeks have shown that large transplants gave a higher yield than medium-sized transplants and that plant spacing of 3×12 inches gave a higher yield than the spacing of 12×12 inches.

Investigations were continued on the effect of oxygen concentrations on the activities of soil micro-organisms which play an important part in plant nutrition. Further results have confirmed that a very low concentration of oxygen must be reached for the inhibition of aerobic decomposition of organic matter by soil micro-organisms, or for the induction of an aerobic decomposition and denitrification of organic matter by them. Measurements of nitrifying and denitrifying activities of micro-organisms in water-saturated soil crumbs were found to show some agreement with the theoretical expectation. The effects of drying soil, and of varying the amounts of inter-crumbs water, on microbial activity have also been studied.

Studies on the chemical changes which occur in the root of red beet and are associated with bolting and with normal flowering, and investigations on the biochemistry of the germination of pea seeds were curtailed owing to the departure of the worker concerned. Results have indicated that for normal germination of peas it is necessary to have the protein sulphhydryl groups in the tissues in a state of dynamic

equilibrium and that this state is maintained by glutathione. It can be implied from this that certain fungicides and herbicides may influence this state and so interfere with germination.

Plant Physiology

At the optimum sowing rates for each row spacing, the yield of shelled peas was found to be 30 per cent higher from 7-inch row spacing than from 21-inch row spacing when harvested at a texturemeter reading of 82; the difference was reduced to 20 per cent when the crop was harvested at a texturemeter reading of 117. Optimum sowing rates differed for the two row spacings at the second harvest but not at the first harvest.

Another experiment in 1960 showed that with onions, 9-inch row spacing gave an average of 10 per cent higher yield than 18-inch row spacing, over a range of plant densities within the rows. Within limits, increasing the plant density increased the yield from 9-inch rows and decreased the yield from 18-inch rows.

Previous results with carrots have shown that rows spaced 12 inches apart gave higher yields than rows spaced 24 inches apart, the number of plants per square foot being the same in each treatment. Results in 1960 indicated that still higher yields could be obtained by reducing the row spacing to seven inches and increasing the number of plants per square foot; the percentage of small roots in the crop was increased but this could be advantageous if this grade were required for canning.

An experimental design which permits the study of the effects of simultaneous variation in both plant density and pattern of plant arrangement, has been developed in co-operation with the Statistics Section and is being tested.

Growth studies on carrots and red beet were continued. Farmyard manure again produced much greater increases in the yield of both crops than the applications of N, P and K, and its effect on the growth rates of the leaves and roots differed only in detail from that in 1957, 1958 and 1959. In all four years, the leaves grew 'logistically', that is, their relative growth rates were a decreasing function of their weights. The growth of the leaves, but not of the roots, with the FYM and no-FYM treatments was effectively summarised in terms of the three constants of a modified logistic equation of growth.

It was found in 1958 that sowing rates of 20 or 30 lb. per acre gave better results with pickling onions than the rate of 40 lb. per acre. Another experiment in 1960 showed that although the 30 and 40 lb. rates gave similar yields of pickling onions (two grades), the 30 lb. rate gave more of the marketable large bulbs and fewer of the unmarketable small bulbs. It also showed that row spacings of 6, 9 and 12 inches did not differ in their effects on the yield.

Previous work has shown that the germination capacity of onion seeds could be affected by the site at which the bulbs were seeded. A recent experiment has shown that the percentage germination can be affected at least as much by the stage of maturity of the seed when harvested, and by the subsequent drying and storage temperature.

Brussels sprouts sometimes produce sprouts which are discoloured internally. It appears that this internal browning is not caused by a pathogen and initial investigations have suggested that it might be a physiological disorder brought about partly by frost.

It was again found that translucent polythene and clear PVC when used in Dutch lights did not give such an early crop of winter lettuce as glass. On the other hand, clear cellulose acetate, and fibre glass, gave just as early a crop as glass. All five materials, however, gave about equally good yields of lettuce.

Irrigation

Further experiments in the field with early summer cauliflowers, variety Finney's 110, have confirmed that with average rainfall, irrigation during the growing period and particularly just before harvesting in a dry period, increased both head weight and curd size. They also indicated that with irrigation, increases in the number of plants per acre, within a certain range, produced little difference in effect on the total weight

of marketable heads but progressively increased the yield in terms of crates per acre, whereas in the absence of irrigation, they produced a progressive reduction in yield.

Experiments in 1960 substantiated previous findings that irrigation of the pea variety Dark-skinned Perfection between sowing and flowering, increased the amount of haulm but not the yield of peas, whereas irrigation at the time the pods were beginning to swell, increased the yield of peas considerably.

Irrigation experiments, using oscillating spraylines, were continued in co-operation with the N.A.A.S. Experimental Horticulture Stations. Owing to heavy rainfall some crops failed to respond to the irrigation treatments but good responses were obtained with peas, lettuce and early potatoes.

An experiment in 1960 showed that the application of dry fertiliser to the soil followed by irrigation gave as good an effect on the yield of lettuce as the application of fertiliser dissolved in irrigation water. This result was not surprising in view of the wet season.

Studies were begun on the temperature of overhead irrigation water when it reaches the soil, and on the effects of changes in soil temperature on plant growth.

Investigation was continued on the powers of different regions of the lettuce root system for absorbing water and mineral salts, using nutrient solutions at different osmotic pressures.

Measurements have shown that annual applications of FYM over a six-year period of vegetable cropping at Wellesbourne have increased the available water capacity of the soil, and that cultivation treatments have had smaller effects than FYM.

Syringing of runner bean flowers with water or irrigating the plants has failed in three successive years to increase the percentage of flowers which gave pods at harvest. Moreover, the weather appeared to have much less effect on the percentage flower set than is generally believed. Other experiments indicated that FYM in combination with adequate water supplies, increased considerably the yield of early pods, and also of the main crop; this followed mainly from increased flower production rather than from increased percentage flower setting.

Entomology

Field experiments again demonstrated that beetles which preyed on the eggs of the cabbage root fly played an important part in the natural control of the pest. Although the total natural mortality of the pest was about the same in 1960 as in previous years, the proportion killed in the egg stage by beetles was much less. A serological method has been used to discover which species of beetles were the most important predators of cabbage root fly.

It has been shown previously that the insecticide dieldrin incorporated in the soil prior to sowing carrots gave an excellent control of the carrot fly. It has now been shown that applications of 1-2 lb. dieldrin per acre can leave sufficient residue in the soil to give an almost full control of the pest five years later. Aldrin was found to be less persistent in the soil than dieldrin, and lindane less persistent than aldrin. Diazinon gave excellent control of carrot fly with little or no carry-over of residue into the second year—a property which has certain advantages.

By means of the sensitive bioassay method developed at Wellesbourne it has also been shown that it takes about four years with a sandy loam soil and about five to seven years with a fen soil for half of the applied amount of the insecticide dieldrin to be lost from the soil. Re-applications of dieldrin might lead, therefore, to undesirable accumulations of residues in the soil, and a suggestion is made as to how this could be avoided. Work is in progress on the development of a method for the detection, identification and semi-quantitative estimation of small amounts of chlorinated hydrocarbon compounds in soils.

The attack of the root aphid on summer lettuce was too light in 1960 for treatments of the soil with insecticides to produce significantly different effects. Some of the treatments, however, gave good control over a severe attack by cutworm.

Study of the biology and control of the carrot-willow aphid was continued. It was found that certain species of *Salix* were preferred as winter hosts, and that migration from willows to carrots occurred between May and early July with a peak between the end of May and early June. The population of aphids was too low in 1960 for tests of systemic insecticides to show appreciable effects.

Plant Pathology

An attempt to improve on the method of controlling crook root disease of watercress as reported last year has given promising results. A more finely ground zinc frit containing a higher proportion of zinc was applied in smaller dosages and to a smaller area of the upper end of the watercress bed. Another method involving a drip feed of a solution of zinc sulphate into the artesian water supply to a watercress bed has also given a good result.

Experiments at Wellesbourne have now shown that *Didymella* stem rot disease of tomatoes in the field can arise from infected seed although the previous experiments failed to demonstrate this.

It has been found that an artificially induced infection of leaves of parsnip plants in the field by the canker causing fungus *Itersonilia* did not increase the number of cankered roots but increased the size of the lesions. It has been found also that when parsnip root material, either infected or uninfected, is left in the soil it can cause an increase in the amount of canker on parsnips grown on that soil during the next two years. This emphasises the importance of rotating parsnips with other crops.

Field experiments were continued at Luddington E.H.S. on the control of clubroot on summer cabbage by means of root dips in suspensions of calomel and aldrin. None of the treatments produced any marked increase in yield, probably because of the unusually wet weather and the fact that the degree of infection was not severe during 1960.

Further progress has been made on the development of a method of controlling leaf and pod spot disease of peas. Soaking of infected seed in either of a number of fungicides at 30°C. eliminated the disease from the seeds but all except thiram and captan were toxic to seedling development.

The *Olpidium* fungus present in the roots of lettuce plants showing big vein disease has been shown to be pathogenically different from *O. brassicae*. Soil treatment with either of the fungicides PCNB or formaldehyde has given control of the disease but neither would appear to be economic for field crops of lettuce.

Field experiments have shown that by using 'mosaic-tested' lettuce seed containing less than 0.1 per cent of seeds infected by the virus, together with adequate isolation from other lettuce crops, it was possible to grow a crop which was virtually free from the disease. Lettuce mosaic virus and cucumber mosaic virus have been isolated from diseased lettuce plants from the field, and some plants contained both viruses. A third virus was isolated which did not produce symptoms when re-inoculated into lettuce.

Studies have been continued on the mechanism of resistance to mildew, *Erysiphe polygoni*, shown by leaves of turnip plants grown in soil watered with solutions of zinc sulphate.

It has been shown that PCNB mixed with soil before brassica seed was sown, gave good control of *Rhizoctonia* infection of the seedlings.

Weed Investigations

Continuous vegetable cropping during four years on what was originally very weedy corn land at Wellesbourne brought about a progressive decrease in the population of weed seeds in the soil down to about one-twelfth of the original numbers. During the fifth year of cropping, however, the wet weather in 1958 prevented the usual degree of weed control from being achieved and this resulted in a doubling of the weed seed population—from one-twelfth to one-sixth. Rotavated plots again contained more weed seeds than ploughed plots.

Further work has confirmed that simazine is a satisfactory alternative to monuron as a residual herbicide for the control of annual weeds in established asparagus beds.

Three chemicals related to simazine were tested again during 1960. As pre-emergence treatments, good weed control was given by propazine with carrots and parsnips, and by trietazine with peas, broad beans, French beans and spring-sown field beans. As a post-emergence treatment, atrazine gave good results with sweet corn.

Promising results were obtained again with amiben and tests were begun on three new selective post-emergence herbicides. A proprietary formulation of BiPC plus OMU gave good results with several vegetable crops, and it appeared that allyl alcohol might prove useful for weed control in Dutch light frames.

The bioassay method reported previously has been used in studies of the rate of disappearance of herbicides from soil in the field. It was found that the rate of disappearance of some herbicides was very much slower during the dry season of 1959 than during the wet season of 1960.

Spray drift. Studies have been continued on the effects of five growth-regulator herbicidal sprays applied at low doses to a range of vegetables. Small (young) plants, although more readily killed than older plants, were more likely to recover from sub-lethal doses and to give higher marketable yields. Four of the sprays produced injury symptoms of a similar type but the degree of injury varied. Less injury was caused by one of the sprays 2,3,6-TBA except on red beet, spinach, and French and broad beans. Morphological injury symptoms have been recorded photographically.

Statistics

As in the past, advice and assistance have been given to the research staff and to the N.A.A.S. Experimental Horticulture Stations and other bodies.

Previous work with red beet had shown that the factors which affected the accuracy of field experiments were highly complicated. Recent work has shown that two cultural treatments which it was thought might reduce the amount of plant-to-plant variability (by improving the percentage and the uniformity in rate of germination of seed) failed to achieve this to any appreciable extent, but succeeded nevertheless in improving the yield of marketable roots. In co-operation with the Physiology Section, a design for spacing experiments with vegetables in the field has been produced which should have advantages over the conventional kind of design. It requires less land and a smaller proportion of guard plants, and permits variation of the area and shape of the area per plant either simultaneously or separately, thus allowing spatial arrangements at different densities to be studied.

A mathematical equation proposed by Japanese workers to express the relationship between plant density and yield has been extended so that it may give a better fit where it previously had been unsatisfactory. A further extension has been made which gives a reasonably good fit to some published data on the relationship between the yields of two species growing in competition with each other.

After a lapse of a year, work was resumed on the genetics of continuous variation in French beans.

The Director has continued to serve on the Advisory Committees of the N.A.A.S. Experimental Horticulture Stations, and to act as Chairman of the Vegetable Working Party which co-ordinates the experimental work on vegetables at these Stations. Mr. Nelder and Mr. Winter also served again on the Protected Cropping Working Party. We acknowledge with thanks the continued close co-operation given by the E.H.S.'s in carrying out field experiments with vegetables in extension of those done at Wellesbourne.

In seed maintenance and multiplication work and in trials of varieties, there was again full co-operation between the National Institute of Agricultural Botany and this Station, and the Director served on the Vegetable Trials Advisory Committee, and the Root and Vegetable Seeds Committee of the N.I.A.B.

Mr. Wright was appointed a member of the Scientific Advisory Committee of the Agricultural Chemicals Approvals Scheme, and Mr. Winter continued to serve on the Natural Resources Committee (Irrigation Study Group). Mr. Roberts served again on the Recommendations Committee of the British Weed Control Council and on the N.A.A.S. Horticultural Herbicides Committee.

N.V.R.S. ASSOCIATION

Chairman of the Association: David Lowe, Esq., Elvingston, Gladsmuir, East Lothian.
Treasurer: Professor T. Wallace, 'Redwings', Old Church Road, Nailsea, Somerset.
Secretary: G. Lesson, Esq., N.V.R.S.

The N.V.R.S. Association, founded in 1958, increased its membership during 1960 from 164 to 199. This increase in the membership is gratifying, and it is hoped that the expansion will continue.

During 1960, three meetings of the Association were held. On 2nd March, 47 members attended a Members' Day at the Station, when talks and demonstrations of various vegetable diseases were given by the staff of the Plant Pathology Section. During the morning of 8th June 1960 the Second Annual General Meeting of the Association was held at the Station; the report of the Association committee and statement of accounts for the past year were adopted, and the Chairman (Mr. David Lowe) and the members of the Association committee were re-elected for the ensuing year. The meeting also approved of the Association committee's recommendations as to the purposes to which the accumulated funds of the Association should be devoted. The primary purpose was the setting up of a fund for the provision of a graduate research scholarship tenable at the N.V.R.S. The committee wish that this objective, involving the major use of the funds, should become widely known, as they feel that it should do much to stimulate membership and strengthen the Association. During the afternoon of 8th June, 41 members were conducted round some of the field experiments concerned with the pea crop.

On 20th October 1960, 58 members attended a Members' Day at the Station. The programme included illustrated talks and field demonstrations of experiments with carrots and of breeding work with Brussels sprouts.

The Association and its objects have been publicised over the past three years, but the best publicity is the personal commendation of a member. We do, therefore, ask all members to pass on details of the Association and its activities to their horticultural friends and explain to them the benefits of joining the Association. The more vegetable growers who join, the stronger will be the link between practice and research. The Association enables growers to keep in touch with the research work being carried out at the Station, and one of the most satisfying and valuable results of the formation of the Association has been the opportunity it has provided for the interchange of ideas and experience between members and research workers.

Forms of application for membership and copies of the rules of the Association may be obtained from the Secretary of the Station.

Visitors

The number of visitors to the Station during 1959-60 was 929, including the following from overseas:—

<i>Australia:</i>	Mr. M. V. Carter, Waite Institute, Adelaide.
	Mr. W. P. Dunk, Chief Irrigation Officer of the State Rivers and Water Supply Commission, Victoria.
	Mr. P. V. Joyner, Shell Chemical (Australia) Ltd.
	Dr. J. H. Palmer, Irrigation Research Station, Griffith.
<i>Austria:</i>	Dr. W. Porzer, Shell (Austria) Ltd., Vienna.

- Canada:* Mr. A. P. Arnason, Research Branch, Department of Agriculture, Ottawa.
Mr. N. W. Holmes, Research Station, Lethbridge, Alberta.
Mr. G. W. Robertson, Central Experimental Farm, Ottawa.
Dr. G. Strachan, Canada Department of Agriculture, Research Branch, Lethbridge, Alberta.
- Egypt:* Mr. A. R. S. Amin, Vegetable Research Section, Ministry of Agriculture, Dokkie, Cairo.
- Finland:* Mrs. Anna-Liisa Varis, Agricultural Research Centre, Department of Pest Investigation, Tikkurila.
- Germany:* Mr. K. H. Martin, Institut für Pflanzenbau, Stuttgart, Hohenheim.
- Holland:* Dr. O. Banga, Wageningen.
Mr. S. K. P. Groot, Delft.
Mr. C. R. Jensma } Bruinsma Hybrid Seed Company,
Mr. L. V. Kunk } Naaldwijk.
Mr. C. J. van der Post, Naaldwijk.
Ir D. C. Post } Wageningen.
Dr. M. Post }
Dr. K. Verhoeff, Naaldwijk.
Mr. C. T. de Wit, Wageningen.
- India:* Mr. M. P. Gupte, Deputy Conservator of Forests, Punjab.
Mr. S. R. Husain, Senior Plant Protection Assistant, Department of Agriculture, Lucknow, Uttar Pradesh.
Mr. P. M. Mamoo Koya, District Agricultural Office, Calicut 1, Kerala.
Dr. N. B. Kulkarni, Sugarcane Disease Investigation Officer, Padegaon, Bombay State.
Mr. D. V. Murthy, Assistant Entomologist, Mysore Department of Agriculture, Bangalore 1.
Dr. Kanwar Singh, Punjab Agricultural Department.
Mr. T. R. Subramaniam, Agricultural College and Research Institute, Coimbatore, Madras State.
- Iran:* Mr. M. Vaezi, Plant Protection Department, Ministry of Agriculture, Teheran.
- Israel:* Dr. G. Stanhill, Agricultural Research Station, Rehovot.
- Malaya:* Mr. A. Yunus, Department of Agriculture, Kuala Lumpur.
- New Zealand:* Mr. R. Close, Crop Research Division, Christchurch.
Mr. W. Cottier, Entomology Division, D.S.I.R., Nelson.
- Nigeria:* Mr. T. M. Greensill, Ministry of Agriculture, Eastern Region, Enugu.
Mr. B. J. S. Lee, Empire Cotton Growing Corporation, Samaru.
- Pakistan:* Mr. N. Ahmad, Department of Plant Protection, Karachi.
Mr. M. A. Anjum, Department of Plant Protection, Dacca.
Mr. M. A. Baluch, Columbo Plan Fellow.
Mr. M. S. Malik, Department of Plant Protection, Karachi.
- Peru:* Dr. P. T. Alvim, Instituto Interamericano de Ciencias Agricolas, Lima.
- Philippines:* Mr. Ramon del Carmen, Mindanao Agricultural College, Musuan, Bukidnon.
Mr. C. J. Palma Gil, Plant Pest Control Officer, Bureau of Plant Industry, San Andres, Manila.
- Poland:* Mr. J. Skierowski, Department of Vegetable Crops, Institute of Soil Science and Cultivation of Plants, Skierniewicach.
- South Africa:* Dr. L. J. Neethling, Shell Chemical Company, Johannesburg.
Mr. T. Bosman, University of Natal.
Mr. J. W. Macdonald, East London.
Mr. E. Strydom, Horticultural Research Station, Pretoria.
- Southern Rhodesia:* Mr. F. Puczyłowski, Henderson Research Station.
- Sudan:* Mr. H. A. A. Eltom, Department of Agriculture, Khartoum.
Mr. Y. K. Kameir, Managil.
- Sweden:* Dr. R. Lamm, Horticultural Research Station, Alnarp.
- Thailand:* Mr. K. Jalavicharana, Chief of the Plant Industry Division, Ministry of Agriculture, Bangkok.
- Turkey:* Mr. M. A. Anbaroglu, Plant Protection Institute, Adana.
Mr. H. Turkmenoglu, Chief of Entomology Laboratory, Plant Protection Institute, Bornova-Izmir.
- Uganda:* Mr. H. G. Laity, Jinja.
Sub-Inspector B. Kibirige of H.H. The Kabaka of Buganda's Police Force.
- U.S.A.:* Mr. H. A. Barthwick, Plant Industry Station, Beltsville, Maryland.
Mr. G. Stafford Brandt, Department of Health, Education and Welfare, Cincinnati 26, Ohio.

Dr. E. W. Davis, Crops Research Division, Agricultural Research Service, Beltsville, Maryland.
 Professor R. W. Fulton, University of Wisconsin.
 Mr. S. F. Haurakan, California.
 Dr. M. F. Kernkamp, University of Minnesota.
 Dr. J. T. Medlar, University of Wisconsin.
 Professor A. Sherf, Cornell University.
 Dr. Neely Turner, The Connecticut Agricultural Experiment Station.
 Dr. J. C. Walker, University of Wisconsin.
 Mr. F. T. Warren, Department of Horticulture, Purdue University, Lafayette, Indiana.
 Mr. D. C. Williams, Illinois.
 Mr. R. Lozanovski, Faculty of Agriculture, Skopje.

Yugoslavia:

In addition, the following 29 parties visited the Station:—

1960

22nd April	...	...	Youth Employment Officers.
10th May	...	...	Professor A. H. Bunting and students of Reading University.
26th May	...	...	Members of the Farming Club of St. Edward's School, Oxford.
30th May	...	...	Meriden and District Young Farmers' Club.
31st May	...	...	N.I.A.B. Variety Trials Advisory Committee.
1st June	...	...	Former students of the North of Scotland College of Agriculture.
9th June	...	...	Members of the Royal Leamington Spa Horticultural Society.
10th June	...	...	The Birmingham and Midland Section of the Royal Institute of Chemistry.
10th and 11th June	...	...	South Wales and West Midland Branch of the Horticultural Education Association.
20th June	...	...	Dr. C. C. V. Batts and students from the Imperial College of Science Field Station. Dr. C. J. Hickman, with staff and students of the Botany Department, the University of Birmingham.
28th June	...	...	N.A.A.S. Officers (Northern Region).
6th July	...	...	Members of the Biometric Society.
7th July	...	...	Staff of the East Malling Research Station.
8th July	...	...	Members of the Eighth International Grassland Congress. Senior pupils of the King Edward VI High School for Girls, Birmingham.
11th July	...	...	Students from the University of Nottingham School of Agriculture, Sutton Bonington. Students and staff of the City of Coventry Training College.
12th July	...	...	The British Commonwealth Scientific Committee.
13th July	...	...	The Vice-Principal and students of the Warwickshire Institute of Agriculture, Moreton Morrell.
15th July	...	...	Staff of Littleton and Badsey Growers Limited, Badsey, near Evesham.
18th July	...	...	Staff and students from Studley College, Warwickshire.
19th July	...	...	N.A.A.S. Officers (Yorkshire and Lancashire Region).
20th July	...	...	Sixth-formers of Brewood Grammar School, Staffordshire.
25th July	...	...	Members of the Sixth Commonwealth Mycological Conference.
27th and 28th July	...	...	N.A.A.S. Horticultural Advisory Officers.
8th September	...	...	Members of the Stratford-upon-Avon Round Table.
20th September	...	...	The N.F.U. Headquarters Vegetables Committee.
27th September	...	...	Five Yugoslavian journalists.

Acknowledgments

Special thanks are given to members of the staff who have carried out duties in addition to their normal work, and mention must be made of those who served on the following committees:—

Library Committee—Dr. Haworth, Mr. Nelder, Mr. Roberts (Chairman) and Mr. Woodroffe;

Glasshouse Committee—Dr. Haigh, Dr. Keyworth, Mr. Norwood, Mr. Winter and Mr. Wright (Chairman);

Canteen Committee—Mr. Austin (Secretary), Mr. Bartlett (co-opted), Miss Clarke, Mr. Cleaver (Chairman), Mr. Lesson (Treasurer), Dr. Salter and Miss Smith. Mr. Roberts and Mrs. George also are given special thanks for carrying out library work during the ten months prior to the appointment of Mr. Woodroffe as librarian on 28th March.

Thanks are also due to other members of the staff who helped in various ways and to all the staff and employees for the loyal manner in which they carried out their work during the year.

Grateful acknowledgment is made to the Executive Committee and the Sub-Committees, and particularly to the Chairman of the Governing Body and the Chairmen of the Committees, for the valuable assistance they have given. We are sorry to have lost the services of Professor P. T. Thomas on the Governing Body and we are grateful to him for the help he has given since 1953.

We offer our warmest thanks to all our friends outside the Station who have kindly given books, seeds, plants and other material, and who have helped in so many ways during the past year.

JAMES PHILP,

17th February 1961.

FARM

By T. J. NORWOOD

Wellesbourne

The acquisition of 96 acres of additional land in September 1959 led to an increase in the acreage of potatoes, cereals and grass grown during 1960. Sixty acres each of wheat and barley were grown and were harvested before the end of September. The yield of grain was up to the average for the farm but owing to the excessive rain during the harvest the straw was of poor quality. The potato crop was above average in yield despite the attack of blight; the haulm was killed by acid spraying before the crop was lifted, and the tubers have kept well in store. From the 120 acres of leys and permanent pasture about 200 tons of silage and 80 tons of hay were made in early summer under good conditions.

Regarding experimental vegetable crops, those planted in the spring grew well and yielded heavy crops but, owing to the wet summer, difficulty was experienced in ripening the onions. Carrots split badly and many of the autumn harvested red beet were too big for culinary purposes. Crops planted in late summer suffered much from water-logging of the soil.

Of the 63 bullocks in the yards during the winter of 1959-60, 19 were sold for beef from the yards and the remainder were put to grass at the end of March and were sold as they reached the required standard from June onwards. Between August and October an additional 81 bullocks were purchased and, after grazing the late summer grass, they have been yarded for the winter. The pedigree herd of Large White pigs was maintained and, of the 296 graded for bacon, 85 per cent were of AA or AA + standard and, from the 48 litters born, 464 pigs were reared. It is estimated that 550 tons of farmyard manure was produced and ploughed into the fields for vegetables.

A large area on the west side of Soakwaters was drained with 4-inch pipes to relieve the water-logging experienced there. Several hedges were cut and laid, and six pairs of new gates were hung, and others repaired to facilitate the movements between the newly purchased land and the original farm.

A number of the huts hitherto used as temporary laboratories have been removed and placed at suitable points over the vegetable growing areas to be used as tool stores and shelters by those engaged in weighing, recording, etc.

Paglesham

At Paglesham the main vegetable crops grown were Brussels sprouts and onions. Various plots of each crop were grown in isolation at opposite ends of the farm to provide nucleus stock seed. Further plots of other varieties were grown to provide material from which to select potential parents for future seed production. In addition, crops of Brussels sprouts from hybrid seed were grown to discover how the progeny behaved under East Anglian conditions. In connection with beet silvering disease, plots of red beet stockings were grown to assist in the study of the spread of infection from silvered plants to healthy crops.

Twenty-six acres of Majestic potatoes were grown and, while the yield was exceptionally high, great difficulty was experienced in harvesting them owing to the very wet autumn weather. The wheat and barley crops were also heavy but, again because of the very wet weather, harvesting was prolonged and a certain amount of grain was lost unavoidably in the process.

During the winter 1959-60 30 bullocks were fed in the yards until April when they were put on to the leys to graze and were subsequently sold for beef during the summer. A further 39 bullocks were bought in the autumn and are now being wintered in the yards. The small herd of breeding sows has been maintained but their progeny is now being sold as stores since the farm buildings proved to be unsuitable for bacon production.

PLANT BREEDING REPORT

By J. C. HAIGH

BREEDING PROJECTS

In addition to the work reported below, progress has been made towards breeding a non-bolting red beet with a single-seeded fruit, a winter cabbage free of rosette heads, an early summer cauliflower of good quality, F_1 hybrid onions, all male asparagus, self blanching celery of improved quality and parsnips resistant to canker. Information on this work will appear in future reports.

Lettuce (L. E. Watts and R. A. T. George)

Among the large amount of material grown and examined in the lettuce trials of 1952-54 (1) was a hybrid seedling line 45634M, of the crisp type, which was bred by Dr. T. W. Whitaker of California and was found at Wellesbourne to be immune from downy mildew caused by *Bremia lactucae* Regel. Crosses have been made between 45634M and several butterhead varieties in order to develop a mildew-immune butterhead type. Immunity was found to be inherited as a simple dominant character, and it has now been transferred to several butterhead-type F_4 progenies which are homozygous for immunity and has also been retained in a crisp type which was developed by selection from the original immune material. Since the development of these progenies has been by segregation rather than by the use of a backcrossing technique (largely because of the difficulty of hybridising lettuce) the F_4 progenies are quite distinct in morphology from existing commercial varieties, although they have, of course, also been selected for desirable commercial characters. These F_4 progenies will be compared with commercial varieties in trials in 1961.

The winter glasshouse lettuce Cheshunt Early Giant has the property of not transmitting the lettuce mosaic virus through the seed. All other varieties transmit the virus to a small extent (up to four per cent), which varies from one variety to another and probably varies also with environmental conditions. In order to transfer the non-transmitting character to summer lettuces, plants of several varieties were crossed with Cheshunt Early Giant. The F_2 generation was exposed to natural infection by the mosaic virus and seed was taken from infected plants which had been selected for late bolting. In the F_3 and succeeding generations, all progenies showing seedling infection were discarded, and from the remainder, selected plants were again exposed to natural infection with mosaic virus and then seeded. Since the amount of transmission is small, it is necessary to grow progenies of several hundred plants in order to have a good chance of detecting an infected seedling; and since the amount, though small, is not accurately known, there is still a possibility that the numbers in each progeny may be too small for infection to be detected. This may be the reason for the fact that in each generation infected seedlings have appeared in the progenies of some plants which had been selected from a progeny showing no seedling infection; nevertheless, there are now progenies which have a 'clean' record over three successive generations. The average transmission over all progenies was 0.67 per cent, and in those progenies showing infected seedlings was 1.79 per cent.

Of the many *Lactuca* spp. tested for resistance to mosaic virus disease by the Pathology Section, only *L. georgica* has shown no symptoms after being artificially inoculated with the virus. Attempts to cross *L. georgica* with *L. sativa* have so far failed, but it has been successfully crossed with *L. virosa*. Lindqvist (5) reported that he had crossed *L. virosa* with *L. sativa* and that the hybrids proved to be sterile. If it proves possible to intercross these two species hybrids, it increases the chances of transferring the mosaic immunity of *L. georgica* to *L. sativa* via this genetic 'bridge'.

Brussels sprouts (A. G. Johnson and G. J. Faulkner)

The methods being developed for the production of hybrid seed of Brussels sprouts in commercial quantities utilise either male sterility in one parent inbred line, or sib-incompatibility within one or both parent inbred lines. The hybrids grown in 1960 were all produced from lines having one or other of these attributes, and therefore it was at least theoretically possible for seed of these hybrids to be produced on a large scale.

Five lines of Cambridge Special were involved—two were S_3 lines which were relatively sib-incompatible; the other three were lines in which 50 per cent of the plants were male sterile, and 50 per cent were heterozygous for the male sterility factor and so were male fertile. The latter three lines were derived from the original variety by one selfed generation followed by two sib-cross generations. Five S_2 lines of Cambridge No. 1 were also involved, four of which were relatively self-incompatible, the remaining one containing the male sterility character.

A test was made to find if hybrid seed could be produced satisfactorily using insects as pollinating agents in nylon isolation cages in the field, with either sib-incompatible or male sterile inbred lines. One of the crosses involved a male sterile line of Cambridge Special with a Cambridge No. 1 line, and the other involved sib-incompatible lines of both varieties. From the former, the male sterile plants gave a mean seed yield of $\frac{1}{4}$ oz. per plant, all of which was hybrid, while all seed harvested from the male fertile line of Cambridge No. 1 was the result of sib-crossing and could thus be used in the multiplication of that line. From the cross of sib-incompatible lines the mean seed yield was $\frac{3}{8}$ oz. per plant, and the seed harvested from the inbred line of Cambridge No. 1 gave 99 per cent of hybrid plants, while the seed from the Cambridge Special line gave only 52 per cent of hybrid plants, the remainder being the result of sib-crossing. These results are encouraging and suggest that large scale production of hybrid seed should be possible.

Shortage of isolation facilities made it necessary to produce the other 23 possible different hybrid combinations of 'Special x No. 1' by hand pollination in isolation bags in the glasshouse. Three combinations set very little seed but the other 22 hybrid families, including the two produced in nylon field cages, were grown in a trial in 1960. The trial consisted of five randomised blocks of plots each containing 20 plants. The general type of all hybrids was early or very early, with medium sized sprouts which were slightly smaller than those of Cambridge No. 1, and of darker colour and greater firmness than those of other early varieties, including Cambridge No. 1. For the first time in trials covering four years at Wellesbourne, the yield of the Cambridge Special parent variety exceeded that of the Cambridge No. 1 parent variety. Comparing the hybrids with the better parent variety, as has previously been the practice, 11 of the 22 hybrids gave a greater yield of marketable sprouts than Cambridge Special, the best showing an increase of 32 per cent.

From the commercial viewpoint, however, comparison with the early Cambridge No. 1 parent was more instructive since the hybrids were more similar in type to Cambridge No. 1 than to Cambridge Special. All but two of the hybrids gave a greater yield than Cambridge No. 1, and ten of them were earlier. At a spacing of 3 ft. square the best hybrid gave a yield equivalent to 8.07 tons per acre of marketable sprouts, which was 53 per cent better than that of Cambridge No. 1.

One of the better strains of the Evesham grower's type and the new variety Irish Elegance both gave yields which did not differ significantly from that of Cambridge No. 1, but they were both slightly later than Cambridge No. 1.

Internal browning of Brussels sprouts (G. J. Faulkner)

The amount of internal browning (I.B.) of Brussels sprouts varies from variety to variety and from season to season. The main symptom of the condition is a discolouration within the sprout, usually between the growing point and the exterior of the button, and varying from a small pinky-brown patch to a semi-circular brown band

of disintegrated tissue. Externally, such a sprout appears to be perfect, the discolouration being detectable only when the sprout is cut open.

Field inspections were made during the winters of 1957-58 and 1958-59 in Bedfordshire, where I.B. occurs frequently. I.B. was seen in both large and small sprouts of widely-differing varieties, on good and bad soils, and before and after frost, but there seemed to be no constant association with any one environmental factor, nor any suggestion that I.B. was primarily genetically controlled. In January 1959 a questionnaire was sent to officers of the N.A.A.S.; no clear lead was obtained from the data collected from all over the country, but there was a suggestion that market types suffered more commonly from I.B. than quick-freeze types.

During 1959 the Physiology Section joined in the project, the Plant Breeding Section looking for evidence of genetic control, and the Physiology Section devising experiments to test the effect of individual environmental factors. Field observations at Wellesbourne during the season 1959-60 suggested that exposure to frost might be a causal factor, since sprouts protected by leaves were found to have less I.B. than others which had been exposed by the removal of the leaves. Very firm sprouts showed less browning than loose sprouts, but sprout size did not appear to be connected with the incidence of browning.

Spring cabbage (A. G. Johnson and G. J. Faulkner)

The breeding material grown in the season 1959-60 consisted of (a) second inbred generation (S_2) lines from selected S_1 plants from each of six commercial varieties; (b) progenies derived separately from each of the S_1 plants by mass pollination with the other selected S_1 plants from the same variety; and (c) F_2 families from inter-varietal crosses between selected non-inbred plants. The parent commercial varieties and four others likely to be of interest were also grown for comparison with the breeding material.

All the material was sown in the third week of July 1959 which has been found by experience to be the correct time of sowing at Wellesbourne for crops intended for early marketing. Nevertheless, by early April 1960 the ten commercial varieties had a general mean of 67 per cent of plants which had bolted without producing marketable heads. The best variety had 44 per cent of bolters, all others had more than 50 per cent and the worst had 95 per cent of bolted plants. These varieties had been chosen in previous trials (4) as being better than average in their general characteristics including freedom from bolting.

In contrast, the whole of the breeding material had a general mean of 29 per cent of plants bolted without producing marketable heads. Of the 57 families grown, 19 had less than 10 per cent of bolters (nine S_2 lines, two mass progenies from S_1 plants, and eight F_2 families). Out of a total of 21 S_2 lines, four had no bolters in a total of 400 plants in all.

Some of the progenies derived by mass pollination of S_1 plants were ready to cut as partially-hearted spring greens by the end of March 1960, which was about two to three weeks earlier than any of the commercial varieties. Reduced vigour in the inbred lines resulted in later hearting in each S_2 line as compared with the progeny derived from the same S_1 parent plant by mass pollination but the order of earliness, however, was the same in the S_2 lines as in the mass pollinated progenies. Thus the mass pollinated progenies were of considerable help in judging the potential earliness of the different inbred genotypes in the absence of inbreeding depression.

Several S_2 lines were obtained which were both non-bolting and potentially early maturing, and selections were made from them for further breeding work. The green colour of these early lines, though acceptable, was not as dark as that of some of the later maturing material. Selections combining, as far as possible, earliness, non-bolting and improved colour were also made from other inbred lines and from one F_2 family.

The transfer of whiptail resistance from wild cabbage to summer cauliflower (L. E. Watts and R. A. T. George)

Varieties of summer cauliflower differ in their susceptibility to 'whiptail' when grown on molybdenum deficient soil, thus indicating that resistance is genetically controlled. Nevertheless, no variety has been reported as being completely free from symptoms when grown under those conditions. Wild cabbage, which showed no symptoms of whiptail when grown on molybdenum deficient soil at Wellesbourne, was crossed with a highly susceptible early summer cauliflower variety, Cambridge No. 6.

The hybrids were found to be almost free from symptoms (slight symptoms were exhibited in two out of 389 F_1 plants, which included reciprocal crosses) while 53 per cent of Cambridge No. 6 showed symptoms of greater severity. Attempts to produce F_2 have failed so far but backcrosses to the cauliflower parent have been made and these will be compared with wild cabbage and Cambridge No. 6 summer cauliflower in 1961 on soil deficient in molybdenum.

Peas (H. Holland and G. J. Frost)

Work was continued in breeding for early maturity and good quality in a winter hardy pea.

In November 1958 seed was sown of the F_3 generation from crosses between maple pea and commercial wrinkled varieties (3), together with seed of a few F_4 generations and selfed seed from first backcross plants raised in the glasshouse. Maple pea and the commercial varieties Onward and Perfected Freezer were sown as controls. The winter of 1958-59 was a moderately hard one, there being 57 nights of air frost, with 15° of frost occurring on 17th January 1959. All the Onward plants were killed, but two out of 200 plants of Perfected Freezer survived and were kept for seed. A high proportion of the hybrid derivatives survived the winter, however, and 142 plants were selected in June 1959 on the basis of earliness, vigour and flavour, the flavour being judged from samples picked in the field at the canning stage.

100 seeds of each of these 142 selected plants were sown in November 1959, together with Onward, Dark-Skinned Perfection, Perfected Freezer, Douce Provence and maple as controls. The winter of 1959-60 was very mild, and although there was a little frost in the second half of January 1960, relatively little natural selection for winter hardiness took place, e.g., the percentage survival of Onward and Perfected Freezer was 42 and 70 respectively.

In May 1960, from those progenies having winter hardiness equal to or better than that of the maple pea, 41 early maturing progenies were chosen which possessed morphological characteristics and vigour similar to those of the commercial varieties. This group consisted of 38 F_4 , 2 F_5 and one backcross. These progenies were harvested when they reached the canning stage (determined by tenderometer) and the peas were kindly canned by the Fruit and Vegetable Canning and Quick-Freezing Research Association at Chipping Campden. During August and September 1960 they were tested by tasting panels both at Chipping Campden and at Wellesbourne, against Dark-Skinned Perfection as control. Three were quite unacceptable, 27 were inferior to the control but the remaining 11 were equal to or better than the control in both flavour and yield; 6 of the 11 had as dark or darker seed colour than the control. The seeds of all 11 progenies were smaller than those of Dark-Skinned Perfection, which is a good character in a canning or quick-freezing pea. The maturity of these progenies ranged from being equal to that of spring sown Kelvedon Wonder (one of the earliest wrinkled-seeded vining varieties) to about 14 days earlier. Further selection and testing will be carried out within these breeding lines.

Tomatoes (J. C. Haigh and E. Miriam Slade)

Progress towards the production of a variety of cultivated tomato resistant to *Didymella lycopersici* (2) has been slowed down by the discovery that the inheritance

of resistance is probably more complicated than at first appeared. The occurrence of unexpectedly large numbers of susceptible segregants in first and second backcross generations from *L. hirsutum* to *L. esculentum* suggests that the inheritance of resistance is under polygenic control.

The search for additional sources of resistance has continued, and several new accessions have been tested, so far without positive result.

SEED PRODUCTION

Nucleus stock seed was produced of the following varieties in 1960:—

Brussels sprouts	..	Cambridge Special at Paglesham.
Onions		Cambridge No. 10 at Paglesham and Wellesbourne.

Plants were grown of the following varieties to produce nucleus stock seed in 1961:—

Brussels sprouts	..	Cambridge No. 1	} at Paglesham.
		Cambridge No. 3	

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CHEMISTRY REPORT

By F. HAWORTH

FIELD EXPERIMENTS

The spring cabbage on each of the three main long-term experiments grew rapidly in the mild conditions which prevailed during the autumn of 1959. However, by the middle of April 1960 more than 85 per cent of the plants had bolted before attaining marketable condition. The crops were cut and weighed but practically no marketable produce was obtained. Many of the plants showed severe symptoms of infection by the cabbage black ringspot virus; this disease was also prevalent in the summer cabbage and autumn cauliflower crops on the nitrogen experiment and was present, but to a smaller extent, in the summer cauliflower and Brussels sprout crops on the cultivation experiment.

Some of the treatments and crops in these long-term experiments (4) were changed at the beginning of the third three-year cycle in 1960. The changes were made to enable the residual effects of previous applications of FYM on crop yields to be measured; to ensure that, so far as possible, the supply of nutrients on the no-FYM plots would be adequate and would not limit yields; to measure the yield responses of the crops to higher rates of application of fertiliser; and to increase the number of different crops grown in the experiments.

Cultivation experiment

Deep ploughing, shallow ploughing with subsoiling, and shallow ploughing alone did not differ in their effects on the yield of leeks, harvested December 1959, but gave higher yields than shallow rotavating as the primary cultivation. The difference between the yields from the ploughing and rotavating treatments was about 40 per cent where FYM and nitrogenous, phosphatic and potassic fertilisers had been applied, but was almost 200 per cent where only nitrogenous fertiliser had been given. The four cultivation treatments did not differ in their effects on the yield of Brussels sprouts, harvested November 1959 to February 1960, except on plots which had received only nitrogenous fertiliser. On these plots, shallow ploughing with subsoiling gave a significantly higher yield than shallow ploughing alone, which itself gave a significantly higher yield than rotavating. Deep ploughing gave a yield between those of shallow ploughing and rotavating and it was not significantly different from either.

The cultivation treatments in this experiment were not altered in 1960 but the manurial treatments were changed from

- B 1. N only, applied after ploughing.
- 2. FYM, P and K before ploughing: N after ploughing.
- 3. FYM before ploughing: N, P and K after ploughing.
- to b 1. N, P and K, applied after ploughing.
- 2. FYM before ploughing: N, P and K after ploughing.
- 3. Residual FYM: N, P and K after ploughing.

The rotation of crops was changed from peas, spring cabbage, leeks and Brussels sprouts to peas, autumn lettuce, summer cauliflowers, leeks and Brussels sprouts and the rates of application of manure and fertilisers were:—

			N		lb. per acre P ₂ O ₅		K ₂ O	
			old	new	old	new	old	new
Early peas	..	..	0	31	36	36	72	72
Autumn lettuce	..	..	—	93	—	36	—	96
Early cauliflowers	..	..	—	155	—	36	—	144
Leeks	..	..	62	93	36	36	72	144
Sprouts	..	..	62	124	36	36	72	144

The rate of application of FYM remained at 20 tons per acre per crop. In addition, plots which had received only nitrogenous fertilisers prior to 1960 were given a base dressing of phosphatic and potassic fertiliser supplying 36 lb. P₂O₅ and 144 lb. K₂O per acre.

Deep ploughing, and shallow ploughing with subsoiling, gave higher yields of summer cauliflower, harvested in June 1960, and of autumn lettuce, harvested in late September 1960, than shallow ploughing or rotavating. In general, the differences were not large, but were statistically significant.

The manurial treatments FYM and NPK (b₂), and NPK in presence of residual FYM (b₃), did not differ significantly in their effects on the yields of summer cauliflower, and both gave a 25 per cent higher yield than NPK fertilisers alone (treatment b₁). With autumn lettuce, however, the yield from treatment b₂ exceeded that from treatment b₃ by about 7 per cent and this difference was significant. The yields from these two treatments exceeded that from treatment b₁ by about 55 per cent.

Of the cultivation treatments shallow ploughing with subsoiling gave the highest yield of peas, harvested in June 1960, while of the manurial treatments, NPK with residual FYM (b₃) gave a 10 per cent higher yield of marketable pods than FYM with NPK (b₂), which itself gave 11 per cent more than fertilisers alone (b₁), both differences being significant.

Nitrogen experiment

The rotation was changed in 1960 from early potatoes, spring cabbage, leeks and summer cabbage to early potatoes, autumn cauliflowers, bulb onions, summer cabbage and red beet.

The autumn cauliflower crop was severely affected by virus disease and failed to mature in the wet, cool autumn. Owing to difficulties arising out of the changes in the rotation, the red beet crop was sown later than had been planned and did not produce beet of marketable size before growth ceased in the autumn.

The rates of application of the fertilisers were changed as follows:—

			N ₁		lb. per acre P ₂ O ₅		K ₂ O	
			old	new	old	new	old	new
Early potatoes	..	..	62	62	36	36	60	144
Autumn cauliflowers	..	..	—	124	—	36	—	144
Onions	..	..	—	62	—	36	—	144
Summer cabbage	..	..	135	186	36	36	48	144
Red beet	..	..	—	93	—	36	—	144

The rate of application of FYM was unchanged at 20 tons per acre per crop.

For early potatoes the responses to the different manurial treatments followed the same pattern as in earlier years: FYM produced an increase in yield of about 25 per cent; hoof and horn meal and nitrochalk in equivalent quantities produced similar yields of potatoes, and the split applications on nitrochalk were less effective than the same quantity of fertiliser applied as a single dose before planting the crop.

Hoof and horn meal and nitrochalk in equivalent quantities produced yields of summer cabbage which were about equal. This result contrasts sharply with those of previous years when the yields from the hoof and horn meal treatment were much less than those from the nitrochalk treatment which supplied the same amount of nitrogen. The reason for this unusual response is not known. The yield response to FYM was smaller than in previous years and averaged about 20 per cent. There was an interaction between the responses to the FYM and nitrogen treatments; the responses to the nitrogen treatments were greater in the absence of FYM than in its presence.

Bulb onions were grown in 1960 for the first time in this experiment and the biggest yield response obtained was to the FYM treatment: this gave an increase in yield of about 54 per cent. The different nitrogen treatments produced yields which did not differ significantly although the highest rate of application of nitrochalk (treatment $4N_3$) gave about a 6 per cent higher yield than treatments organic N_1 , $4N_4$ and $4N_4$.

NPK-FYM factorial experiment

The rates of application of the fertilisers were changed in 1960 as follows:—

			lb. per acre					
			N_1		$P_1 (P_2O_5)$		$K_1 (K_2O)$	
			old	new	old	new	old	new
Early potatoes	..		31	62	18	18	48	96
Spring cabbage	..		46	93	18	18	36	72
Carrots	..	..	15	15	18	18	48	48
Red beet	..	..	31	62	18	18	48	96

The rate of application of FYM was unchanged at 20 tons per acre per crop.

The responses of early potatoes, carrots and red beet to the various fertiliser treatments were different from those obtained in previous years and the most striking divergencies were in the responses to potash fertilisers. From 1954-59 the potash treatments produced consistent and fairly large increases in the yields of red beet and early potatoes whereas, in 1960, applications of potash fertilisers produced no increase in the yield of red beet and only a small increase in the yield of early potatoes. The response of carrots to the potash treatments, although larger than in previous years, was small.

During 1954-59 the phosphate treatments did not produce significant increases in the yields of red beet, carrots and early potatoes (except for an increase of 20 per cent in the yield of early potatoes in 1955). In 1960, however, the phosphate treatments in the absence of FYM produced small but statistically significant increases in the yields of early potatoes and carrots but had no effect on yields if applied together with FYM; with red beet, the phosphate treatments produced small non-significant increases in yield both in the presence and absence of FYM.

In previous years, applications of nitrogenous fertilisers gave significant increases in the yield of early potatoes (about 25 per cent on average) but in 1960 the nitrogen treatments did not increase the yield of early potatoes. Treatment N_2 gave a 20 per cent higher yield of red beet than treatment N_1 and treatment N_3 gave a further 5 per cent increase in yield. Treatments N_2 and N_3 depressed the yield of carrots in the absence of added potash but increased yields when potash was also applied. The response patterns for red beet and carrots were similar to those of the previous years.

As before, the FYM treatment produced the largest increases in the yield of each of the three crops; the yield increases were: red beet 79 per cent, early potatoes 28 per cent, and carrots 12 per cent.

Runner beans

The experiment (5), started in 1957 to measure the response of runner beans to soil physical conditions and nutrient supply, was continued. The results showed that, in the absence of added fertilisers, the residual effect on the yield of beans of an application of FYM made in 1957 was still considerable in 1960, but that the yield so produced was lower than that produced by fertilisers, applied annually, alone. Where fertilisers had been applied annually in addition to the original application of FYM in 1957 the yield of beans produced in 1960 was the same as that from fertilisers alone—in previous years FYM applied in 1957 with annual applications of fertilisers had produced higher yields than fertilisers alone. It would thus seem reasonable to conclude that the non-nutritional residual effects of the FYM applied in 1957 had disappeared by 1960.

SOIL AERATION (D. J. Greenwood)

Aeration of soil may affect crop growth in two ways; first by altering the activities of the soil micro-organisms and in consequence the amounts of nutrients available to plants, and secondly by affecting the respiration of plant roots and thus their ability to take up nutrients. The general purpose of the work is to find the effects of different concentrations of oxygen on nitrification, denitrification, and soil organic matter decomposition and, by using these processes as indicators of oxygen availability, to help to develop a theory of oxygen distribution in soil. On the basis of such a theory and a knowledge of the effect of oxygen concentration and of temperature on the microbial processes, it should be possible to predict their extent in a soil subjected to a sequence of climatic conditions. By similar reasoning, it may be possible to determine how the physical condition of soil, through limiting oxygen supply, restricts the roots' abilities to take up nutrients. The study of oxygen distribution in soil has been resolved into two components; one of determining the rate of diffusion of oxygen into water-saturated soil crumbs, and the other of determining the rate of diffusion of oxygen in the gas filled spaces between the crumbs.

Effect of oxygen concentration on the activities on some soil micro-organisms

The effect of oxygen concentration in the water immediately surrounding the micro-organisms in soil on their activities was studied by three independent techniques. The first depended on measuring the rate of oxygen diffusion into water-saturated crumbs of known size (2); the second made use of the known relation between oxygen concentration and yeast respiration (6); while in the third, the effect of oxygen partial pressure on microbial processes taking place in soils held at reduced water content was studied. All three techniques gave similar results.

Nitrification in soil, previously stimulated by percolation with ammonium sulphate solution under an atmosphere of air, was not inhibited by a reduction in oxygen concentration until low values were reached; a 30 per cent inhibition resulted from a 6×10^{-6} M solution of oxygen. Denitrification was stimulated by percolating soils, held under different oxygen partial pressures, with glucose/ammonium sulphate/potassium nitrate solutions. No loss of nitrate occurred when the atmosphere surrounding the crumbs was air; all the oxygen required for metabolism was thus provided by the atmosphere. Under low oxygen partial pressures some of the oxygen was obtained from reduction of nitrate, with a consequent diminution of oxygen uptake. When the oxygen concentration surrounding the organisms was 2.5×10^{-6} M the oxygen uptake was 30 per cent less than in the presence of excess oxygen. In all experiments the loss of nitrate plus nitrite nitrogen was equal to the loss of total nitrogen. It follows, therefore, that there was no loss of nitrogen unless the oxygen concentration was less than about 5×10^{-6} M.

Organic matter decomposition in soil in the absence of oxygen proceeds with the formation of volatile fatty acids, whereas in the presence of oxygen it proceeds without their formation (3). Since anaerobic decomposition of soil organic matter is slow, very sensitive methods would be required to detect any of the volatile fatty acids formed. However, casein-digest is rapidly metabolised by micro-organisms under anaerobic conditions and its decomposition in soils, held under different oxygen partial pressure, was studied. No volatile fatty acids could be detected even when 80 per cent of the soil crumbs were under anaerobic conditions and the maximum oxygen concentration anywhere in the system was $3 \times 10^{-5} \text{M}$. Evidence was obtained that volatile fatty acids, produced in the anaerobic pockets, diffused into regions where there was sufficient oxygen to maintain aerobic metabolism which resulted in their disappearance from the system as a whole.

The respiration of casein-digest oxidising organisms, like that of each of four soils of widely different pedological types, was not inhibited unless the oxygen concentration was reduced to less than about $5 \times 10^{-6} \text{M}$.

It was concluded, therefore, that respiration of soil micro-organisms and aerobic organic matter decomposition by these organisms were not inhibited and that anaerobic organic matter decomposition and denitrification were not induced unless the oxygen concentration surrounding the organisms was reduced to less than about $5 \times 10^{-6} \text{M}$.

Effect of oxygen diffusion on microbial activities in water-saturated soil crumbs

The first of the methods used above for finding the effect of oxygen concentration on microbial activities also enabled tests to be made of theoretical predictions of activities in soil crumbs. The predictions, which were based on Fick's Law of Diffusion, required measurements to be made of the microbial respiration rate when oxygen was not limiting, of the size and water content of the crumbs, and of the oxygen partial pressure in the atmosphere. When the respiration rate was constant and independent of time the theoretical and experimental values for the rates of respiration, nitrification and denitrification agreed within 25 per cent of each other. For denitrification the theoretical argument is much more complex and thus the observed agreement between the theoretical and experimental values might be capable of an alternative explanation.

Effect of oxygen diffusion through the gas filled space in columns of soil crumbs containing inter-crumbs water

Work has been started to find out if it is possible to account for the effects of varying amounts of inter-crumbs water on the respiration of columns of soil crumbs on the basis of previous measurements of gaseous diffusion through such systems (1). Measurements were made of the respiration rates of a series of tubes of soil, each of which contained a sieved fraction of crumbs, held under different water regimes. For each tube a relation was obtained between the water content and the depth from the soil surface. Theoretical respiration rates were calculated in terms of this relation and the respiration rate when oxygen was not limiting. Experiments, so far confined to crumbs of 0.6-0.8 mm. and 1-2 mm. diameter, have shown some agreement between respiration rates experimentally observed and those calculated theoretically.

Effect of drying on microbial activities in soil

Control experiments, for work on aeration, with a soil of one type showed that there was no inhibition of its ability to decompose glucose, to nitrify, and to respire under fully aerobic conditions until the water content had been reduced to 28 per cent (moisture content at field capacity was 38 per cent). The possibility that inhibition at lower moisture contents than 28 per cent resulted from the killing of some of the micro-organisms was eliminated by drying the soil, re-wetting it, and immediately measuring microbial activities; no inactivation took place unless the water content

had been reduced to less than 10 per cent. Using the pressure membrane apparatus, Dr. Salter of the Irrigation Section kindly determined the water-content/tension curve of the soil. A water content of 28 per cent was reached when the tension was 2.0 atmospheres and thus when all the capillaries with radii greater than 7.5×10^{-5} cm. had been drained. The radius of a live bacterium is of a similar order of size and the reason for the inhibition of activity at a water content of less than 28 per cent may have been that the organisms were not completely surrounded with water and thus could not make the maximum use of their absorbing surfaces. In addition, since drying caused a contraction of the soil crumbs it may also have caused some of the micro-organisms within the soil crumbs to have become mechanically isolated from their nutrients.

FLOWERING OF RED BEET PLANTS (S. P. Spragg)

In the report for 1959 (7) the possibility that changes in the metabolism of phosphorylated organic compounds may be important in the induction of flowering was mentioned. Before more information on this aspect could be obtained, it was necessary to separate the phosphates present in plants and to examine the changes in the individual compounds resulting from different temperature treatments. For this purpose a study has been made of the quantitative chromatography of organic phosphates using ion-exchange resins.

This work has shown that a complete separation of the constituents of mixtures containing nucleotides and sugar phosphates was not possible using one ion-exchange resin only. It seemed that a preliminary separation into broad chemical groups was necessary prior to the final separation. Under these conditions it was found possible to separate quantitatively, complex mixtures of organic phosphates using the resin Deacidite FF (Permutit Company Ltd., England), and displacing the ions from the resin with increasing concentrations of formic acid followed by increasing concentrations of a formic acid/sodium formate mixture. Synthetic phosphate mixtures were used in the foregoing experiments but attempts have also been made to separate and to estimate the different phosphate fractions extracted from plant material. The results have shown that quantitative extraction and concentration of the organic phosphates from plant material was made more difficult by three factors. The first was the comparatively low concentration of the compounds in plant material; the second was the presence of pigments which were soluble in the extracting solvents and quickly inactivated the ion-exchange resins; and the third was the thermal instability of the compounds which made it difficult to concentrate the extracts quantitatively. Because of these complicating factors it appears that considerably more work will be necessary before a quantitative estimate of the various phosphate fractions can be achieved.

GERMINATION OF SEEDS (S. P. Spragg and Patricia M. Lievesley)

The results of a more detailed examination of the chemical changes in the sulphhydryl groups of germinating and developing pea seeds have emphasised the importance of this grouping in controlling metabolic processes. In the germinating seed, it has been possible to show indirectly that there is a steady state of equilibrium in the redox state of the protein sulphhydryl groups in the tissues. This is actively maintained by glutathione, although other mercaptans may influence the equilibrium considerably. Arising out of this is the implication that chemical compounds which could disturb this equilibrium, could interfere with the germination of the pea seed. Examples of such compounds are unsaturated aliphatic compounds such as allyl alcohol, water soluble mercaptans or chemicals which hydrolyse to form mercaptans, maleic hydrazide and other maleic acid derivatives, and compounds of lead and of mercury. Some of the chemicals which are used as fungicides and herbicides have one or more of these reactive centres.

A similar equilibrium was shown to exist in two-day old pea seedlings and the steady state constant for this tissue was different from that in intact seeds. The difference between the two constants indicates that oxidation of the sulphhydryl group may be important for mitosis and may well be a quantitative measure of the changes in metabolism necessary to allow a cell to divide.

Measurements made on the maturing pea seed showed that the changes in the oxidation state of the sulphhydryl groups were most marked in the subcellular fractions; these changes are thought to be important in controlling the rate of maturation of the seed and were found to be particularly sensitive to variations in its water content.

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THE YIELD OF LEEKS AS AFFECTED BY SPACING AND SIZE AT TRANSPLANTING

By F. HAWORTH

In the southern and midland counties of England, leek plants are normally raised in a seed-bed and transplanted into the field in late June or early July. In the northern counties and in Scotland seed is often drilled directly into the field in March or April. The spacing of the rows of the drilled crops, and of the rows and plants within the rows of the transplanted crops varies from area to area.

Observations made on crops of leeks growing in manurial experiments at Wellesbourne in 1955 and in 1956 suggested that both the spacing of the plants and their size at transplanting could have large effects on the final yield of the crop, and experiments were done in 1957 and 1958 to measure these effects.

Experimental

Soil

The experiments were sited on an alluvial sandy loam of the Newport Series and for the 1957 experiment farmyard manure (FYM), at 50 tons per acre, was applied before ploughing in early March, while in 1958 the site had received FYM at the rate of 50 tons per acre annually for the preceding three years. In each experiment, fertiliser was applied in mid-June and supplied 240 lb. K_2O , 36 lb. P_2O_5 and 75 lb. N each per acre.

Layout and treatments

In the 1957 experiment there were seven randomised blocks each containing four plots. Two sizes of transplant, large (mean weight per plant 9.0 gm.) and medium (mean weight per plant 3.7 gm.) were planted on 5th July at each of the spacings 6×12 and 12×12 inches. The plot size was 2×2 yd. excluding a single guard row around each plot. The transplants had been grown in a separate seed-bed from seed, variety The Lyon, sown in late March. The crop was harvested in mid-December, the roots of the plants were trimmed off to within one inch of the stems, and the plants were washed but the leaves were not trimmed.

In the 1958 experiment there were three randomised blocks each containing six plots. Two sizes of transplant, large (mean weight per plant 20.5 gm.) and medium (mean weight per plant 5.7 gm.) were planted on 7th July at each of the spacings 3×12 , 6×12 and 12×12 inches. The plot size was 2×2 yd. excluding one guard row around each plot. The crop was harvested in the same way as in the 1957 experiment.

Results

The yields of leeks obtained in both experiments are given in the table.

Yield of leeks. lb. per 4 sq. yd.

Size of transplant Spacing inches				1957			1958		
				Medium 3.7 gm.	Large 9.0 gm.	Mean	Medium 5.7 gm.	Large 20.5 gm.	Mean
3 × 12	...	...	...				28.2	45.8	37.0
6 × 12	...	...	...	31.7	43.1	37.4	23.1	34.1	28.6 ±2.00
12 × 12	...	...	...	19.4	26.2	22.9	12.1	18.7	15.8
				±1.98			±2.84		
Mean	...	...	...	25.5	34.8	30.1	21.1	33.2	27.1
Standard errors are for differences.				±1.41			±1.65		
Number of degrees of freedom				18			10		
1 oz.=28.4 gm.									

In 1957 the large transplants outyielded the medium by about 36 per cent at both spacings, and the closer spaced plants outyielded the wider by about 64 per cent at both sizes of transplant.

In 1958 the difference in yield between large and medium transplants was greater than in 1957; it averaged about 57 per cent and did not vary significantly with spacing. With the large transplants the highest yield was obtained from plants spaced at 3×12 inches. This yield was significantly higher than that from plants spaced at 6×12 inches, the latter yield was itself 75 per cent higher than that from plants grown at the widest spacing of 12×12 inches. With the medium transplants the closest spacing gave the highest yield but the difference between the yields from the 3×12 and 6×12 inch spacings was not statistically significant. The plants spaced at 6×12 inches outyielded those grown at the widest spacing of 12×12 inches by about 90 per cent.

Discussion

In these experiments the yield of leeks was greatly influenced by both the size of the plant at transplanting time and the spacing of the plants in the field. The highest yield of leeks was obtained from large transplants planted at the closest spacing, while large transplants at the widest spacing gave the heaviest mean weight per plant. Castranova *et al* (2) used a range of spacings from 2×16 to 8×16 inches and reported that the highest yield was obtained from plants at the closest spacing, while plants grown at the widest spacing had the greatest mean weight per plant. Betzema (1) found that the yield of leeks was also influenced by the degree of rectangularity of the spacing of the plants and obtained the highest yield from plants spaced at 8×12 inches. From the practical viewpoint, it would seem that the highest yield of leeks would be expected from large transplants planted at a density in excess of four plants per sq. ft. at square or near-square spacing, and that plants should be grown under very good conditions in the seed-bed to obtain large transplants.

From the experimental viewpoint, the results emphasise the need to take into account the size and uniformity in size of the plants at transplanting time and the spacing of the plants in conducting experiments on the growth and yield of leeks.

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PLANT PHYSIOLOGY REPORT

By E. J. WINTER

COMPETITION STUDIES (J. K. A. Bleasdale and R. Thompson)

Work on the effects of spatial arrangement of plants and of crop density on yield has been continued and a new layout for field experiments has been tested. Using normal factorial randomised block designs the effects of row spacing on the yield of peas and onions has also been investigated.

Peas of the variety Dark-Skinned Perfection were sown on 21st-22nd April at three inter-row spacings (7, 14 and 21 inches) and four sowing rates ranging from 6 to 26 stones per acre. There were thus 12 main treatments and each plot was split to give two dates of harvest. The yield of shelled peas from the 7-inch rows at the first and second harvests was respectively 30 per cent and 20 per cent higher than that obtained from the 21-inch rows. These yield differences were attained at the optimum sowing rates for the particular row spacings. At the first harvest, when the mean of the texturemeter readings was 82, row spacing did not appreciably affect the optimum sowing rate which was approximately 13 stones per acre. The optimum sowing rates at the second harvest, however, when the mean of the texturemeter readings was 117, were 16, 14 and 12 stones per acre for the 7, 14 and 21-inch rows respectively.

The experiment with onions was similar to the above pea experiment but only three inter-row spacings (9, 13½ and 18 inches) were used and the plant stand was varied from 6 to 16 plants per sq. ft. The mean effect over all plant densities was that the 9-inch rows gave a 10 per cent higher total yield than the 18-inch spacing but whereas the yield from 9-inch rows increased as plant density within the rows increased, the yield from 18-inch rows decreased. Thus, with 10 plants per sq. ft., the yields expressed as tons per acre were respectively 27.1, 25.1 and 23.3 for the 9, 13½ and 18-inch row spacings.

The effect of plant density and spatial arrangement on the yield of the above crops was also studied using a systematic layout. The essential features of this layout are that in each plot the positions of the plants are defined by a grid formed by the intersections of the radii and circumference of concentric circles. A progression of spacings along the radii is arranged to give a continuous range of plant densities while the patterns of plant arrangement remain constant in any one plot. Different patterns of plant arrangement were used in separate plots. The results obtained with peas and onions demonstrated that single plants given the same area of ground yielded more when that area was a square than when it was a rectangle with the ratio of the short side to the long side of 1:12. In both cases the plants were placed at the centres of their allotted areas.

This type of systematic layout was also used in experiments on cabbage, carrots, red beet, lettuce and French beans. These experiments have provided data which are being used to assess the value of the layout and to devise methods of statistical analysis. Mr. Nelder of the Statistics Section has been responsible for much of the development of the design and his co-operation at all stages of this work is gratefully acknowledged.

SPACING OF CARROTS (R. Thompson and J. K. A. Bleasdale)

Field experiments during the past three years have shown that decreasing the inter-row spacing from 24 inches to 12 inches increased the yield of ware carrots by 25 per cent when the number of plants per unit area was constant. An experiment in 1958 showed that increasing the sowing rate from 1.5 lb. to 2.3 lb. per acre did not affect either the total or ware yield at any of the row spacings used. Nevertheless it was felt that higher total yields than those obtained at 12-inch inter-row spacings might

be achieved at even closer row spacings particularly if the sowing rate was increased. It was anticipated that these higher total yields might be achieved only at the expense of some reduction in the mean size of roots but as there is a demand for small carrots for canning a preliminary experiment seemed justified.

A randomised block experiment with four replications of the following three treatments was sown in the field on 3rd June:—

- (1) Seed drilled at 2 lb. per acre in rows 12 inches apart, giving 13 plants per sq. ft.
- (2) Seed drilled at 3 lb. per acre in rows 7 inches apart, giving 23 plants per sq. ft.
- (3) Seed broadcast at 18 lb. per acre giving 48 plants per sq. ft.
(equivalent to drilling 6.5 lb. per acre).

The variety used was Clucas' Stump Rooted which is a red-cored type. Each plot was split to give three harvest dates—the beginning of September, October and November. Table I summarises the yields of roots obtained, the data having been converted to tons per acre to facilitate evaluation.

TABLE I
*Effect of row spacing, sowing rate and harvest date on
the yield on carrot roots. (tons/acre)*

M.A.F.F. grade	Row spacing and sowing rate/acre	Date of harvest			Mean
		September	October	November	
A. Total marketable roots above $\frac{1}{2}$ -inch diameter	12 inch 2 lb.	17.4	28.8	31.9	26.0
	7 inch 3 lb.	18.6	32.8	36.2	29.2
	Broadcast 18 lb.	17.4	25.4 (± 1.61) ¹	23.8	22.2 (± 0.93)
	mean	17.8	29.0 (± 0.93)	30.6	
B. Ware above 1 inch diameter	12 inch 2 lb.	13.3	27.3	30.6	23.7
	7 inch 3 lb.	12.7	30.2	34.8	25.9
	Broadcast 18 lb.	3.0	17.7 (± 1.85)	20.7	13.8 (± 1.07)
	mean	9.6	25.0 (± 1.07)	28.7	
C. Canning $\frac{1}{2}$ –1 $\frac{1}{2}$ inch diameter	12 inch 2 lb.	16.8	16.6	17.8	17.7
	7 inch 3 lb.	18.3	24.1	20.4	20.9
	Broadcast 18 lb.	17.4	23.2 (± 1.80)	16.7	19.1 (± 1.04)
	mean	17.5	21.3 (± 1.04)	18.3	

¹Standard error of the difference between means with 23 degrees of freedom.

A–B=yield of canning roots in a ware crop.

A–C=yield of ware roots in a canning crop.

The results indicated that total yields higher than those obtainable from sowing rates of 2 lb. per acre in rows 12 inches apart could be achieved by using closer rows and higher sowing rates; the latter would give a higher proportion of small roots which would be advantageous when small carrots were required for canning. There would appear to be little merit, however, in broadcasting seed at very high sowing rates.

GROWTH STUDIES (R. B. Austin)

Carrots

In 1960, for the fourth successive year, a growth analysis was carried out on the carrot crop of the Chemistry Section's NPK-FYM factorial experiment. The experimental treatments and sampling procedure were the same as in 1957 to 1959 (1, 4). The application of 20 tons per acre of FYM significantly increased the yield of roots at harvest, from 20.4 tons (no FYM plots) to 23.4 tons per acre. The yield of roots was also significantly increased by the application of potash, but not by the application of nitrogen or phosphate.

During the period of exponential leaf growth, the net assimilation rates and relative growth rates of plants on the + FYM plots were 25 per cent greater than those of plants on the no-FYM plots. As in 1957, 1958 and 1959, the maximum difference between the size of the leaves on the + FYM and on the no-FYM plots occurred at the end of the exponential period of leaf growth. In 1960, when exponential leaf growth lasted for seven weeks, as compared with four to six weeks in 1957, 1958 and 1959, the weights of leaves on the + and no-FYM plots differed by a factor of 4.1 as compared with about 3.0 in previous years. The reasons for these year to year differences in the duration of the exponential period of growth are at present unknown.

As before, the growth of the leaves was adequately described by a modification of the logistic equation in which the weight of leaves, T , was replaced by $T^{\frac{1}{2}}$. The constant k of the logistic equation (1) was between 15 and 20 per cent greater for plants on the + FYM than for those on no-FYM plots. The mean values of the constants changed from year to year, despite the substitution of solar radiation or of any other time scale for time in days. The year to year variations in k are believed to be due to the effects of variations in the amounts of soil water available to the plants which occurred from year to year. In predominantly wet growing seasons k was greater than in dry years, thus suggesting that if a term expressing the extent of depletion of available soil moisture were incorporated into the time scale, the values for k might be more constant from year to year.

No simple modification of the logistic equation has been found to fit the root data and the primary reason for this appeared to be that relative root growth rate was a function both of root weight and of leaf weight. A model for the description of root growth rates based on this assumption is being tested, but rigorous testing is difficult since root and top weights are highly correlated. In addition, examination of the growth curves for the roots showed that, until the age of about five weeks, 'root' (i.e., hypocotyl and primary root) weights were many times greater, and relative root growth rates many times less than had been expected, assuming exponential growth to take place in the early stages. Anatomical examination of hypocotyls and young taproots indicated that there was a large proportion of non-active cortex during the early stages of growth and that as secondary growth took place the proportion of cortex to secondary tissue was progressively reduced. Using the estimated weight of the cambium and secondary tissue as 'root' weight, it was found that the anomalous early growth pattern was replaced by a curve showing early growth as approximately exponential.

Red beet

A growth analysis of the beet crop on the Chemistry Section's NPK-FYM experiment was made, using the same treatments and method as were used in 1959 for the carrot and red beet crops. The rates of applications of inorganic nitrogen and potassium were doubled in 1960 as compared with previous years (4). However, the largest significant effect was that resulting from the application of 20 tons FYM per acre, which increased the yield of marketable roots at harvest in November from 5.1 tons (no-FYM plots) to 8.7 tons per acre. The application of nitrogen significantly increased the yield of roots at harvest from 6.3 tons (no nitrogen plots) to 7.4 tons per acre. The yield of roots was not affected by the application of potash or phosphate.

The pattern of crop growth was similar to that found in 1959. During the exponential period of leaf growth, which lasted until the age of seven weeks, the net assimilation and relative leaf growth rates were 10 and 12 per cent respectively greater in plants from the +FYM plots than in those from the no-FYM plots.

Leaf and root growth are being examined in more detail using the methods described for the carrot crop above.

ONION INVESTIGATIONS (R. B. Austin)

Pickling onions. A trial was carried out at Efford during 1960, in which the treatments comprised all combinations of the following factors:—

Rates of sowing	..	20, 30 and 40 lb. seed per acre.
Row spacings	..	6, 9 and 12 inches apart.
Varieties		New Brown Pickling and Giant Zittau.

A layout of three randomised blocks was used and the main plots, comprising all combinations of the row spacings and rates of sowing, were subdivided for varieties. The plots were dressed with 10 cwt. per acre of an inorganic fertiliser compound containing 6 per cent nitrogen, 15 per cent phosphate (P_2O_5) and 15 per cent potash (K_2O). Seed was sown on 4th April and the onions were harvested on 19th August. After drying and cleaning, the bulbs were graded into four sizes using 1 inch, $1\frac{3}{8}$ inch and $1\frac{5}{8}$ inch riddles. No samples were retained for quality assessment since in previous years it was found that quality was not significantly altered by variations in row spacings or sowing rates. Both varieties were known to yield onions of acceptable quality for pickling.

Large and significant differences in the yield of onions in the four size grades were produced by the sowing rate but not by the row spacing treatments. The yields in all size grades of the two varieties at each sowing rate are shown in Table II. Increasing the sowing rate from 20 to 40 lb. per acre decreased the mean bulb size but did not significantly affect the total yield of bulbs. Although the yield of No. 1 picklers increased as the sowing rate was increased, the proportion of onions less than one inch in diameter, which are normally unsaleable, increased from 14 per cent of the crop at the 20 lb. per acre sowing rate to 33 per cent at the 40 lb. sowing rate.

TABLE II

*Effect of sowing rate on yields of onions in four size grades.
Efford 1960*

Sowing rate and variety	Yield in tons per acre in each size grade			
	less than 1 inch in diameter	No. 1 picklers 1 inch to just under $1\frac{3}{8}$ inches in diameter	No. 2 picklers $1\frac{3}{8}$ inches to just under $1\frac{5}{8}$ inches in diameter	greater than $1\frac{5}{8}$ inches in diameter
20 lb. per acre				
Giant Zittau	2.5	4.8	6.8	7.2
New Brown Pickling	3.8	7.4	7.0	5.2
30 lb. per acre				
Giant Zittau	4.1	6.5	6.0	3.9
New Brown Pickling	6.0	7.9	6.4	3.8
40 lb. per acre				
Giant Zittau	6.3	8.3	5.2	1.8
New Brown Pickling	8.6	8.9	4.6	2.2
s.e. of diff. (12 d.f.)	±0.41	±0.55	±0.76	±1.15

The mean total yield of bulbs from the variety New Brown Pickling was 23.9 tons per acre, which was significantly greater than the yield of 21.1 tons from Giant Zittau. The greater yield of New Brown Pickling was attributed to the greater general vigour of the variety, together with the higher percentage germination of its seed, as compared with Giant Zittau.

The results agreed in general with those of previous years (2) in that at sowing rates greater than 30 lb. per acre as much as one-third of the crop consisted of small onions, and that greater yields of pickling onions were not obtained when rows were 6 inches, as compared with 9 or 12 inches apart.

Environmental effects on onion seed. Previous work (2) indicated that variations in percentage germination of onion seed were produced by growing genetically similar bulbs on to seed at different centres and that this was responsible for some of the variation in onion crop yields. In extension of this work, uniform bulbs of the variety Cambridge No. 10 were selected from a crop grown at Paglesham in 1958. These bulbs were grown on to seed at Wellesbourne in 1959, and various treatments were applied so that, in 1960, seed was available from each of the 12 combinations of the following factors:—

Date of seed head harvest		17th August 1959 (seeds 'doughy'). 27th August (most seeds mature and black). 8th September (all seeds ripe, capsules splitting).
Seed head drying temperature	..	25°C. and 35°C.
Seed storage temperature		— 20°C. and 25°C. (in desiccators over calcium oxide).

Mean seed weight and laboratory percentage germination were determined for each lot of seed, and the effects of the treatments on the final yields of bulbs were assessed in a field experiment in which each of the 12 lots of seed was sown at the rate of 12, 24 and 36 lb. seed per acre. The mean weights of the seed harvested on 17th August, 27th August and 8th September were 2.65, 3.76 and 4.36 mg. respectively. Seed head drying temperature only affected the mean seed weight of the heads harvested on 17th August, when seed dried at 35°C. had a mean weight of 2.35 mg. as compared with 2.85 mg. when the seed was dried at 25°C. There were significant differences in stand and yield of bulbs grown from the 12 lots of seed. Most of the variation in yield was caused by differences in stand resulting from differences in the percentage germination of the seed. However, by making adjustments for the effects of variations in stand on yield it was shown that the only significant effect of the treatments on the 'corrected' yields was a reduction obtained by drying the immature seed at 35°C., as compared to the other treatments. It may be concluded, therefore, that only when the mean seed weight was less than about 2.5 mg. was its vigour significantly lower than that of fully ripened seed. This suggests that in wet seasons, when seed yields and quality are low because of deterioration and sprouting of the seed before harvest, good seed might be obtained by harvesting before the heads are fully mature and by drying them artificially at a temperature of about 25°C.

This experiment is being repeated and experiments on the effects of variations in the inorganic nutrient content of seed on germination, etc., are in progress in the glasshouse, using watercress.

INTERNAL BROWNING OF BRUSSELS SPROUTS

(J. K. A. Bleasdale and R. Thompson)

The essential symptom of internal browning (I.B.) is the presence of a discolouration within the sprout, usually above the growing point and between it and the exterior of the button, and varying from a small pinky-brown patch to a semi-circular

brown band of disintegrated tissue. The discolouration is seen only when the sprout is cut open; externally the sprout appears to be perfect.

During the past few years I.B. has caused increasing concern among growers of Brussels sprouts. As former studies in the Plant Pathology Section failed to reveal any pathogenic cause, investigations are now being made to determine whether I.B. is a physiological disorder.

During the late summer of 1959, a questionnaire was sent out to growers and 37 replies were received indicating that 23 growers had seen I.B. at some time in their crops. Nineteen associated I.B. with a particular part of the picking season and of these 14 stated that I.B. occurred in the later part of the picking season or at least from November onwards. Twelve growers thought that the occurrence of I.B. was connected with cold weather. Twenty growers had noticed that the I.B. had been worse in some years than in others; 12 growers gave dates and of these none mentioned the winter of 1958-59, but six mentioned the winter of 1957-58. A comparison of the weather records taken at Wellesbourne during these two years showed that the early winter of 1957-58 had been particularly cold, whereas the early winter of 1958-59 had been exceptionally mild. Thus, the main outcome of the questionnaire was a suggestion that there might be some association between the incidence of I.B. and the severity of frost. Sprouts, attached to intact portions of stems, were therefore subjected to artificial freezing approximating in severity to the cold spells experienced during the early winter of 1957-58. This consisted of keeping the sprouts at -7°C . for 16 hours then at $+2^{\circ}\text{C}$. for 8 hours, the cycle being repeated three times. The sprouts were then kept at laboratory temperature (18°C .) for five days before being examined. Although sprouts from the same population of one variety were used in three experiments of this type, the amount of I.B. induced by freezing varied greatly from experiment to experiment. Evidence now available indicates that the susceptibility to I.B. of plants in the field varies greatly from plant to plant, and it is thought that the amount of I.B. induced by artificial freezing depended on the nature of individual plants used. In one experiment, in which susceptible plants were fortuitously used, 54 of the 78 sprouts which were frozen developed symptoms similar to those of field I.B., whereas none of the 18 control sprouts, which were kept at laboratory temperature throughout the period, was affected.

Further work is in progress in co-operation with the Experimental Horticulture Stations, and with the Plant Breeding Section; reference is made in the Plant Breeding Section's report to field data supporting the view that frost may be a factor causing I.B.

PROTECTED CROPPING

Glazing materials (J. K. A. Bleasdale and R. Thompson)

Studies on the effect of different glazing material on the growth of lettuce overwintered in frames have been continued (3). During the winter 1959-60 lettuces were grown under standard Dutch lights 'glazed' with clear PVC, clear cellulose acetate, fibre glass, glass, and a double layer of translucent polythene. Each plot consisted of a small frame covered with two Dutch lights and there were five replicates in a randomised block layout.

The lettuces were harvested when they reached a marketable size and there was no significant difference between either the number or the total weight of marketable lettuce cut from under any of the glazing materials. The dates by which half the total number of marketable lettuce had been cut were not significantly different for glass, cellulose acetate and fibre glass and were, respectively, 16th, 17th and 17th April. The dates for PVC and polythene were significantly later than the above dates and were 26th and 27th April respectively. Previous results also indicated that lettuce grown under glass were earlier than those grown under PVC or polythene.

Records revealed that the air temperature under cellulose acetate and fibre glass were, during daylight, usually only slightly lower than those under glass, whereas those under the PVC and polythene were usually $2-5^{\circ}\text{C}$. lower. This temperature difference

probably accounted for some of the observed difference in the earliness of the crop. Moreover, it is thought that, in the presence of condensation, less light was transmitted by the PVC and polythene than the other materials and this may also have played a part in delaying maturity.

Acknowledgments

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IRRIGATION REPORT

By E. J. WINTER

IRRIGATION OF CAULIFLOWERS (P. J. Salter)

Previous experiments (8) showed that early summer cauliflower required a plentiful supply of water from rain or irrigation throughout its life, in order to give maximum yield. Further work (9), however, indicated that in a year of average rainfall, provided that there was enough moisture in the soil at planting time to ensure satisfactory establishment, only two or three irrigations between planting and harvest time were sufficient to ensure a reasonable, though not maximal yield. In dry weather, irrigation just before cutting began was found to increase both head weight and curd size.

In 1960 the response of the variety Finney's 110 to four watering treatments, at five plant spacings, was investigated in an experiment with a factorial design having two randomised blocks of plots. From the various irrigation treatments which had previously been found to benefit cauliflowers, three commercially practicable ones were chosen. The fourth 'watering' treatment was an unirrigated control. All the plots were allowed to receive natural rainfall. The five plant spacings ranged from 34×34 inches to 12×12 inches. The experiment was sited on fertile soil to which a base dressing of a complete fertiliser had been added before planting, and subsequently treatments consisting of three levels of nitrogen top-dressing were used in an attempt to ensure that adequate soil nitrogen was available at each of the plant spacings.

In order to reduce the size of the experiment and to exclude those treatment combinations unlikely to be of commercial interest, only nine of the possible fifteen nitrogen and spacing treatment combinations were used with each watering treatment.

The results confirmed that irrigation just before or during the harvest period substantially increased both head weight and curd size, except at the widest spacing, but in the absence of irrigation the weight of marketable heads per acre was greatly influenced by the plant spacing. At spacings progressively less than 24×24 inches there was a progressive reduction in yield in the absence of irrigation, but with irrigation the yield was held fairly constant. However, when the yield of the crop was measured in terms of crates per acre, the results showed that, with irrigation, progressively higher yields, though of smaller curds, were obtained with a progressive reduction in the plant spacing.

The nitrogen and spacing treatment combinations chosen did not, under the conditions of this experiment, result in any significant yield differences attributable to the different nitrogen top-dressings, although there was a tendency towards nitrogen depressing the yield.

IRRIGATION OF PEAS (P. J. Salter)

Two experiments were carried out to determine the response of the pea variety Dark-Skinned Perfection to two different irrigation treatments before flowering and three different irrigation treatments after flowering.

Seed for the first experiment was sown on 1st April 1960, in soil that was at field capacity and, throughout the experiment, all plots were protected from rain by means of movable glass shelters (11). Five randomised blocks with a split plot layout were used, pre-flowering treatments being given to the main plots and post-flowering treatments to the sub-plots.

The results indicated that irrigation between sowing and flowering time increased haulm weight but did not increase the yield of shelled peas. Irrespective of watering treatment prior to flowering 0.5 inch of water applied when the pods were beginning

to swell increased the yield of shelled peas by about 20 per cent, but slightly delayed maturity.

Seed for the second experiment was sown on 19th May 1960 in soil with a moisture deficit of 1.48 inches. The treatments were the same as for the first experiment except that the plots could not be protected from rainfall until one week before flowering, by which time the crop had received 2.29 inches of rain. The effects of the treatments on yield of shelled peas were found to be similar to those obtained in the first experiment. 0.5 inch of water applied to the crop when a sample of shelled peas had a tenderometer reading of 90, increased the yield of shelled peas by approximately 45 per cent.

The results of these two experiments support previous findings (9) and indicate that good increases in yield can be obtained by irrigating a pea crop when the pods are beginning to swell.

IRRIGATION OF A ROTATION OF VEGETABLE CROPS

(F. Lucy C. Blackwall and E. J. Winter)

Field experiments to determine the responses of different crops to irrigation were continued at and in co-operation with Luddington, Efford and Rosewarne Experimental Horticulture Stations of the N.A.A.S. These experiments were not protected from rain which in the summer of 1960 interfered not only with the watering treatments but also with the general culture of some of the crops. Nevertheless even in this wet season some yield increases were obtained as a result of irrigation.

With early summer cauliflowers at Luddington, one set of plots was watered whenever the irrigation indicator (10) showed a moisture deficit of one inch; another set was watered whenever a similar deficit had arisen according to the modified Penman estimate. As in the previous year, yields from these two sets of plots did not differ significantly (standard error—4.8 per cent of the mean). The marketable yield from these plots was equivalent to over 600 crates per acre. The plants for this experiment were raised during the winter in an unheated glasshouse; there were indications that the plants which were watered weekly during this stage of their growth gave a higher yield of marketable curds than those which were watered once each fortnight. The differences in yield, though not statistically significant, tended to confirm results obtained previously at Luddington and Wellesbourne (2).

At Rosewarne, winter cauliflowers were planted in July 1959 and harvested during March and early April 1960. The soil moisture deficit at planting time was 3.70 inches, and in October it was 6.50 inches on the unwatered plots; on 13 occasions the deficit on watered plots exceeded half-an-inch. All the plots, however, received 36 inches of rain from November to April and consequently none of the irrigation treatments affected the crop yield.

Peas were included in the experiment at Luddington; one inch of water applied at the time of petal-fall significantly increased the yield of shelled peas by 21 per cent as compared with that from plots which had received rain only. The application of one inch of water two weeks before flowering, when the soil moisture deficit was 1.5 inches, in addition to one inch applied at petal-fall, significantly increased the yield of peas by 40 per cent and of haulm by 30 per cent. In previous experiments at Wellesbourne (9), watering before flowering had not increased the yield of peas.

At Luddington also, the application of one inch of water to restore the soil to field capacity before sowing summer lettuce increased the marketable weight of the crop by 28 per cent and the number of marketable heads by 27 per cent, as compared with the yield of plots which were not watered before sowing. 0.6 inch of additional irrigation when the roots had reached a depth of ten inches gave no further increase in yield.

Potatoes were grown in the experiments at all three stations. At Efford, 5 cwt. per acre of nitrate of soda was applied as a top dressing to one half of each plot in a split-plot layout, while different watering treatments were applied to the main plots. The top-dressing had no effect on yield. During this experiment rainfall amounted

to five inches, half of which fell a few days before harvesting began. Restoring the soil to field capacity by watering on the two occasions when a one-inch deficit had arisen, significantly increased the yield of early potatoes by 35 per cent and the number of tubers by 27 per cent, when compared with the yield from un-irrigated plots. The effect on tuber number might be of practical importance in the production of seed potatoes.

The early potatoes at Rosewarne received 6.3 inches of rain. None of the irrigation treatments increased the yield of tubers but all increased the yield of haulm; for example, irrigation with totals of 4.7 inches, 3.2 inches, and 1.6 inches of water in addition to rain, significantly increased the weight of haulm by 48 per cent, 39 per cent and 24 per cent respectively, as compared with the weight of haulm from plots which received rain only.

At Luddington, as might be expected in a wet summer, none of the irrigation treatments affected the yield of main crop potatoes.

Certain non-vegetable crops of local interest were included in the rotation at Rosewarne. With anemones, planted in July and harvested during the winter, the soil was restored to field capacity whenever the deficit reached half-an-inch; this treatment which involved watering 17 times, significantly increased by 70 per cent the number of blooms with stem length exceeding 12 cm., as compared with the yield of plots which had received no additional water.

APPLICATION OF NUTRIENTS DISSOLVED IN IRRIGATION WATER (P. J. M. Sale)

Some growers apply fertilisers dissolved in the irrigation water to certain crops but as yet there has been no critical assessment of the effects of this practice. Possible advantages of applying nutrients already dissolved in water are that they are then more rapidly available to the crop particularly in a dry season, and that this method of application requires less labour, and may do less damage to the plants than the application of dry fertiliser to the soil.

The following field experiment was performed in order to find if there were any differences in crop growth brought about by the two methods of application of fertiliser. The experiment, laid out in five randomised blocks of plots, was on lettuce, variety Borough Wonder, sown on 28th June. Where fertiliser was used in a treatment it consisted of equal parts by weight of potassium nitrate and calcium nitrate applied at the rate of 1 oz. per sq. yd. In one treatment the fertiliser was dissolved in half-an-inch of irrigation water applied as an overhead spray, the last $\frac{1}{8}$ -inch of the application being water only. In another treatment the fertiliser was applied dry to the soil and this was followed by half-an-inch of irrigation water. The control treatment consisted of the application of half-an-inch of irrigation water only. Four such applications were made during the growth of the crop which was not protected from rainfall. It was found that the fertiliser significantly increased the marketable crop yield. However, the yields produced by the two methods of application of fertiliser did not differ significantly from one another but since the unusually heavy rainfall of 1960 maintained the moisture content of the soil at field capacity during almost the whole period of growth of the crop, any other result would have been unexpected; the same result might not be obtained in a dry season.

TEMPERATURE OF IRRIGATION WATER (P. J. M. Sale)

Temperature measurements under an oscillating sprayline in the field have indicated that the temperature of the irrigation water when it reaches the soil will be determined largely by the prevailing atmospheric conditions, and to a lesser extent by the droplet size and length of trajectory, rather than by the original temperature of the water when it leaves the nozzle of the sprayline. Under conditions favouring evaporation, as may occur in the summer, it was found that irrigation water originally

brought to air temperature was cooled during its passage through the air. No measurements have yet been made regarding the extent and duration of any alteration of the soil temperature which might be caused by the quantities of water commonly applied by overhead irrigation in the field, but measurements will be made during the coming season.

Before starting on a detailed study of the temperature of irrigation water and its effect on plant growth, it was decided to make a preliminary investigation of the effect of changes of soil temperature on plant growth, and hence the following experiments were carried out. In the glasshouse, lettuce plants of the variety Cheshunt 5B were grown in sand in six-litre cans. Three times each week for five weeks, starting two weeks after pricking out the seedlings, each can was flooded with sufficient water at 40, 55, 70, 85 or 100°F. to bring the whole of the sand to that particular temperature. After every watering the sand in each can regained glasshouse temperature (70°F.) within a few hours. When harvested, nine weeks from sowing, the plants had produced considerable leaf growth but little heart.

In one experiment where the seed was sown on 22nd March, there were no significant differences in fresh weights of tops between plants given any of the temperature treatments. The fresh weights of the roots, however, tended to increase with the increase in treatment temperature; those given the 40°F. treatment were significantly lighter than any of the others, and those given the 100°F. treatment were the heaviest.

In another experiment the seed was sown on 22nd August; no significant differences in fresh weights of tops or roots were found. The fresh weights tended to be reduced, however, as the treatment temperature approached either extreme, i.e., plants given the 40°F. and the 100°F. treatments tended to be smaller than those given the 70°F. treatment, while those given 55°F. and 85°F. treatments were intermediate.

EFFECTS OF IRRIGATING WITH IMPURE WATER (J. B. Williams)

From time to time reports have been received of the yellowing of crop leaves following irrigation with river water. The effects of contaminants in irrigation water are being investigated, especially those of synthetic detergents of the alkyl aryl sulphonate type which are known to be only partially destroyed by the normal bacteria of sewage works (7).

The growth of lettuce and carrot in sand culture was found to be markedly reduced by watering with nutrient solutions containing 50 mg. per litre of a commercial detergent powder, whereas peas were more tolerant of this particular detergent. No indication was obtained that the detergent concentration in the River Avon water was high enough to harm these three crops. 1960 was a comparatively wet season, however, and consequently there was a much greater volume of water to dilute the detergent in the river than there would have been during a dry season.

STUDIES ON ROOT SYSTEMS (D. H. Drew)

Experiments in the glasshouse on absorption of water and mineral salts by the upper and lower regions of root systems were continued, using the method previously described (3). Lettuce seedlings of the variety Cheshunt Early Giant were pricked out into sand on 16th September 1959. The treatments, begun on 27th October, included three in which nutrient solutions, having osmotic pressures of one, two and four atmospheres, were added to the whole root zone. The effects of these treatments were compared with those produced when two- and four-atmosphere solutions were added to the upper or lower part of the root system, while the remainder of the root system received rain water. Where the total amounts of nutrient added to the root systems were equal, the fresh weights of the heads were also equal, regardless of the distribution of the nutrient. No significant yield difference resulted from applying solutions with the three different concentrations to whole root systems. The results indicated that

in the dull weather of this late autumn experiment (during the course of the treatments the average daily solar radiation, measured in the open, was 64 gm. cal. per sq. cm.) mineral nutrition was not limiting growth at any of the concentrations used.

From 5th March to 8th April 1960 (average daily solar radiation of 172 gm. cal. per sq. cm.) some of the above treatments were applied to radishes, variety Crimson Globe, which were sown on 4th February. The same total fresh weight per plant was produced when a four-atmosphere solution was added to the lower part or to the whole of the root system, as when a two-atmosphere solution was added to the whole root system. When the two-atmosphere solution was restricted to the lower part of the root system a smaller plant resulted.

On 10th February 1960, lettuces, variety Cheshunt 5B, were pricked out into sand in cans of a diameter and depth of one foot. Each lettuce was planted in the centre of an inner zone, separated from an outer, annular zone by a wire mesh cylinder covered with waxed dress net. Roots could penetrate this partition, but water and dissolved salts could not (4). The treatments, during the course of which the average daily solar radiation was 260 gm. cal. per sq. cm., consisted of flushing one or both zones with rain water or an appropriate nutrient solution every two or three days. When a four-atmosphere solution was restricted to the inner or outer zone and rain water was added to the other one, the fresh weights of the heads produced were equal to those produced when a two-atmosphere solution was added to both zones. This confirmed that under some conditions lettuce plants were able to absorb all the minerals they needed through a part of the root system when that part was supplied with a sufficiently concentrated nutrient solution.

During July 1960, when the average daily solar radiation was 364 gm. cal. per sq. cm., the treatments described in the previous paragraph were applied to lettuces, variety Borough Wonder, and also a treatment in which a four-atmosphere solution was applied to both zones. Treatment of both zones with a two-atmosphere solution increased the fresh weight of heads over that produced when four-atmosphere solution was added, either to both zones or to only one zone. The moisture stress imposed on the plant by the more concentrated solution may explain the reduction in growth when four-atmosphere solution was added to both zones, but not when the four-atmosphere solution was applied to only one zone. The cause of the reduction in growth with the latter type of treatment is being further investigated.

STUDIES ON THE MOISTURE CHARACTERISTICS OF SOILS (P. J. Salter)

The assessment of the maximum amount of water available to plants which a given soil can hold depends upon the accurate determination of field capacity (the upper limit of available water) and permanent wilting percentage (the lower limit). Methods generally employed for determining these values do not use soil in its natural state and experiments were carried out, therefore, to compare the accuracy of such methods with that of determinations made on undisturbed soil.

The determination of field capacity by finding the moisture content of soil samples taken after heavy rain or irrigation and when drainage had almost ceased, gave more accurate and more consistent results than the suction-plate method, in which a standard suction was applied to a soil sample artificially wetted in the laboratory.

With some soils permanent wilting percentage determined by the sunflower technique (5) on undisturbed cores differed significantly from that determined on crushed soil samples. For critical work, the results obtained with undisturbed soil cores were preferred to those obtained from crushed soil samples. The desiccator method (6) of determining permanent wilting percentage was found to be insufficiently accurate for the present work where a precise measurement of the available water capacity of soils was required.

The effects of annual applications of farmyard manure and of different cultivation treatments over a six-year period on the available water capacity of a sandy loam soil have been measured by the methods mentioned above as being preferred. The results

showed that the FYM applications had produced a significant increase in the available water capacity of the soil while the different cultivation treatments had influenced the available water capacity to a lesser extent. Two papers on this work are in the press.

FACTORS AFFECTING THE SET OF RUNNER BEAN PODS

(F. Lucy C. Blackwall)

Continuing the investigation previously reported (1), the set and yield of runner beans in the field was studied in relation to irrigation, manuring and other factors. The following experiment was laid out in the form of six randomised blocks of three main plots which were split for manurial treatments and contained 12 plants per main plot. Seedlings of the variety Streamline were planted out in the field on 11th May 1960. The application of 20 tons per acre of FYM, in combination with irrigation from the early green bud stage at the rate of 0.5 inch whenever the accumulated loss from an evaporation tank reached 0.75 inch since the previous irrigation, increased the early yield up to the end of July by 57 per cent; similarly manured plots, irrigated on the same basis but from the time the flowers first showed red, about three weeks later, produced an increase in early yield of only 16 per cent as compared with plots receiving neither FYM nor irrigation. Irrigation (whether applied from the early green bud or from the first red flower stage) without FYM, had little effect on early yields (7+ per cent) or on yields up to mid-season. FYM without irrigation increased early yields by 12 per cent, rising to 43 per cent by mid-season (end of August).

The study of flower setting was continued throughout the season. A similar pattern of fluctuations in percentage flower set was obtained in the 1960 season to that obtained in the two previous seasons, despite the differences in weather in these years. Apparently, therefore, the weather has much less effect on flower set than has been supposed.

Over three years the heavier yields of runner beans produced following adequate rainfall or irrigation, have been found to be largely associated with an increase in the number of pods harvested in consequence of the production of a greater number of runner bean flowers rather than an increase in the percentage set of the flowers.

Syringing the open flowers of the varieties Streamline, Kelvedon Marvel and Princes, with water early in August tended to reduce the percentage of flowers which set pods and hence the yield of pods, as happened also in the two previous seasons. In these varieties also the efficiency of insect pollination varied considerably during the season, and changes in the extent of cross pollination were shown, in the variety Streamline, to be related to the nectar-collecting habits of *Bombus* spp.

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ENTOMOLOGY REPORT

By D. W. WRIGHT

THE BIOLOGY AND NATURAL CONTROL OF THE CABBAGE ROOT FLY (T. H. Coaker and Jennifer Worrall)

Investigations were continued on the factors contributing to the natural control of cabbage root fly on brassica crops. Field experiments similar to those carried out in 1959 (6) to determine the importance of predation by ground beetles on the eggs and on the subsequent survival of the pest, were repeated to cover the first and second generations of cabbage root fly attacking early cauliflowers and summer cabbages, respectively. In general, the findings were similar to those obtained in the previous year with lower numbers of eggs recorded in samples from treatments harbouring a high beetle density and, conversely, high egg numbers from those with a low beetle density. There was little relationship, however, between the day-to-day egg loss and beetle activity but the overall seasonal totals of egg survival and beetle numbers from each treatment were highly correlated.

The estimated contribution of egg loss by predation to the total mortality measured between the egg and pupal stage, in 1960, was between 60-70 per cent, a lower proportion than previously estimated (1). The total mortality in all stages was as in previous years 95 per cent, thereby leaving some 20-30 per cent in both generations unaccounted for, since larval and pupal parasitism contributed only about one per cent of the total mortality. This unidentified loss in population numbers may possibly occur in the newly hatched larvae, due to their failure to find the plant roots, and is being further investigated. The experiment was duplicated on two sites and the sites produced greater differences in mean number of pupae per plant, and in crop yield, than did treatment effects on the same site. The yield level at each site was more closely related to the number of plants attacked than to the mean number of pupae per plant. Thus, severely wilted plants on one site had a mean of 6 pupae per plant, and on the other site had a mean of 13; unwilted plants had means of 5 and 10 pupae per plant respectively on the two sites. This evidence supports previous findings that the extent of loss in yield is not always closely related to the degree of infestation but can be modified in either direction by other environmental factors, e.g., soil moisture.

A serological method was used to determine the actual predators of cabbage root fly amongst the complex of carabids found on brassica plots at the N.V.R.S. Representative samples of each species were collected throughout the season and their gut-contents were tested against anti-cabbage root fly serum obtained from rabbits. The presence of cabbage root fly tissue or egg contents in the beetle was demonstrated by the formation of a white precipitate produced by the combination of antigen from the cabbage root fly and antibody from the rabbit serum.

Of the 19 species tested, 14 showed positive reactions, and of these the five most important in order of numbers trapped were *Bembidion lampros* (Herbst.), *B. quadrimaculatum* (Linn.), *Harpalus aeneus* (Fab.), *H. rufipes* (Deg.), and *Feronia vulgaris* (Linn.). The combined number of trapped beetles in the above five species constituted over 80 per cent of the total numbers of carabids caught on brassica plots at Wellesbourne in 1960.

THE CONTROL OF CARROT FLY (D. W. Wright)

Field experiments have shown that aldrin, dieldrin and lindane, when mixed into the soil before the seed is sown, are very effective in controlling the carrot fly. Residues of these insecticides remain active in the soil for a number of years after application, and long-term experiments are being carried out to determine the relative persistence

of these chemicals in fen and mineral soils (at Mepal, Isle of Ely, and Wellesbourne, respectively). In these experiments, begun in 1955, 1956, 1958 and 1959, the insecticides were incorporated into the top four inches of soil, and in each of the following years the land was ploughed to a depth of eight inches and then cultivated and cropped. By comparing the carrot fly infestation in carrot and parsnip crops grown on insecticide treated and untreated soils, the relative persistence of the various insecticide residues in the soil could be assessed. Thus, on mineral soil, 2 lb. aldrin per acre gave a complete control of carrot fly for five years after application, whereas lindane used at the same rate gave complete control for two years only after application, and thereafter its effectiveness declined sharply each year. In fen soil, aldrin was likewise more persistent than lindane, and more than double the amount of insecticide was required in each case to give persistence comparable to that on the mineral soil.

Residues of dieldrin were more persistent in both fen and mineral soil than were those of aldrin or lindane. Thus, in mineral soil, dieldrin at 1 lb. per acre gave complete control of carrot fly for five years after being applied, whereas with aldrin used at the same rate the control became partial in the second year.

As a further indication of the comparative persistence of residues of lindane, aldrin and dieldrin, infestation and yield data were obtained in 1960 from early sown carrots grown on fen soil in an experiment begun in 1956. Each of these insecticides was applied in 1956 at the rate of 2 lb. per acre. On the carrots, harvested in late July 1960, the mean percentage root attack by carrot fly was 71.0, 28.0 and 1.0, for the lindane, aldrin and dieldrin treatments respectively as compared with 64.5 per cent attacked on the untreated plots. The yields of unattacked roots were 2.3, 7.2 and 11.7 tons per acre respectively for the three insecticide treatments and 1.7 tons for the untreated plots.

As in 1958 (5) the cool, moist conditions in 1960 enhanced the effectiveness of certain of the soil insecticides. This was especially marked with dieldrin and diazinon. Moreover, of the 14 different dieldrin treatments used in the various long-term experiments their residues gave, except in one case, a higher level of carrot fly control in 1960 than in the dry season of 1959. The extent of these improvements in performance was greatest where the lower dieldrin rates had been used recently, or where the dieldrin had been applied at a higher rate and had been in the soil for a long period, thus leaving a low level of residue of dieldrin in the soil. With aldrin, treatments expected to give high residue levels in the soil in 1960 also gave improved levels of carrot fly control as compared with 1959. Where residue levels were low, however, a further decline in their effectiveness occurred in 1960. Lindane residues in the soil, from a more limited range of treatments, showed a general decrease in performance in 1960 when compared with 1959. More information on the mode of action of these insecticides on the carrot fly is required before their differing performances can be fully explained.

Diazinon worked into the soil gave, as in 1958 (5), an excellent control of the carrot fly. It was used in both liquid and granular formulations which were rotavated into the soil before sowing. There was no difference in performance between the formulations and, when used at 3 lb. diazinon per acre, the control of the carrot fly was only slightly better (not significant) than where half this rate was used. Carrots grown in 1960 on soils treated in the previous year with diazinon at rates of from 1 to 3 lb. per acre showed no reduction in carrot fly attack as compared with those from untreated soils, thus indicating little or no carry-over of diazinon residues in the soil from season to season. Therefore, in contrast to dieldrin, there would appear to be little chance of 'build up' of this chemical in the soil.

BIOASSAY OF INSECTICIDE RESIDUES IN SOILS

(G. A. Wheatley and J. A. Hardman)

Continuous use has been made during the past year of the sensitive bioassay method (2) for estimating residues of certain chlorinated hydrocarbon insecticides in soils. Residues of dieldrin and heptachlor present in the soils of a number of long -

term field experiments on the control of carrot fly have been assayed. The results have confirmed the extreme persistence of dieldrin in soil in England (3). At doses of from 1-4 lb. dieldrin per acre, about four years are required for half of the insecticide to be lost from a sandy loam soil and about 5-7 years in the case of a highly organic fen soil. Data obtained for heptachlor shows that it is somewhat less persistent than dieldrin but insufficient time has elapsed since it was applied for its rate of loss to have been established accurately.

Further studies on the error components associated with the bioassay technique have shown that errors in assaying soil samples in the laboratory are similar in magnitude (about 7-10 per cent of the means) to those involved in obtaining soil samples from field plots (2). Therefore, the standard errors for estimates of residues in field plots are about ± 10 -14 per cent of the mean values and it seems unlikely that this can be much reduced with the methods available at present. Since the rate of loss of dieldrin is equivalent to about 15 per cent per annum, it is impossible to obtain significant differences between the amounts present in two consecutive years, although it will be possible to estimate trends of residues over a number of years and thereby obtain the necessary information on average rates of loss.

Where a crop such as carrots is grown intensively in short rotations, insecticide may be re-applied by growers when appreciable amounts of earlier applications still remain in the soil. Thus there is a danger of residues accumulating to undesirable levels when a persistent material such as dieldrin is used. Although insufficient time has elapsed to establish whether and to what extent this 'build up' may occur in practice, theoretical considerations suggest that the residue level for a given insecticide should tend to reach a maximum value which will depend on soil conditions, dose and frequency of application. It has been possible, however, to calculate a sliding scale of reduced doses for dieldrin shown in the table, based on the dose and frequency of application (crop rotation length), required to restore the concentration of dieldrin (half-life four years) in the top four inches of soil to the desired value for carrot fly control (4). The use of this interim recommendation should prevent excessive residues occurring until such time as more precise information can be obtained.

*Amounts of dieldrin (lb. per acre) required to restore the concentration in the top four inches of soil**

Initial dose lb./acre	Interval between applications, years					
	1	2	3	4	5	6
0.75	0.4	0.5	0.5	0.6	0.6	0.6
1.5	0.9	1.0	1.0	1.1	1.2	1.2

*Reproduced from *Plant Pathology*, 9, 148.

In much of the published information from the U.S.A., there are indications that high initial losses of insecticide occur immediately after treating soils. During the summer of 1960 an attempt was made to discover if this happens on fen soil in East Anglia. The soil was treated with 0.75 and 1.5 lb. dieldrin per acre and, after the insecticide had been mixed in to a depth of four inches, soil samples were obtained immediately and also after 5, 12 and 19 days. In all cases, the residues recovered, as indicated by bioassay, were similar to the amounts applied and no marked loss of dieldrin could be demonstrated.

Bioassay methods are non-specific because the responses of the test organisms do not identify the toxic compounds involved. These methods, therefore, are only suitable when the identity of the toxic residue is known beyond reasonable doubt, or

when it is sufficient to know that samples do or do not contain biologically active components. It is now well known that many of the chlorinated hydrocarbon insecticides change to varying extents into allied biologically active compounds after application. For example, aldrin and heptachlor become epoxidised to form dieldrin and heptachlor epoxide respectively and, whenever either of the two former compounds are used, their residues are inevitably mixtures containing the appropriate epoxide as well as the parent compound. The components of such mixtures cannot be readily measured by biological methods alone. On the other hand, chemical methods specific for the parent compounds do not detect the biologically active derivatives and this leads to underestimates of the amounts of active residues present. Paper partition chromatography, however, offers a means of detecting, identifying and semi-quantitatively estimating small amounts (1-2 $\mu\text{g.}$) of chlorinated hydrocarbon compounds. A preliminary study has shown that this technique can be applied to residues in soils but difficulties have been encountered in the attendant extraction and 'clean-up' procedures when residues are less than about 0.1-0.2 ppm. Attempts are being made to improve the sensitivity and range of the method so that it can be used in parallel with the bioassay technique to provide more precise data on residues. Furthermore, where complex mixtures of insecticides occur, as in soils which have been treated with several compounds, paper chromatography appears at present to be the only practical way of assessing residues.

LETTUCE ROOT APHID (J. A. Dunn)

Lettuce root aphid galls on poplar were more numerous in 1960 than in the two previous years but cool and wet weather prevented the winged migrant aphids from establishing colonies on lettuce. As a result, the overall attack on lettuce was extremely low and fewer lettuce root aphids were found at Wellesbourne than in any year since the work on this insect began in 1955. Thus, although several insecticide treatments were carried out, insufficient root aphids were present to show any significant differences between the numbers found on untreated and on treated plots. The lettuce, however, suffered from a high attack of cutworm (*Agrotis segetum* (Schiff.)) and it was possible to observe the effect that the treatments, applied against root aphid, had on this attack. Only pre-sowing soil treatments had been applied, and those of endrin all considerably reduced cutworm numbers, the lowest application rate ($\frac{1}{4}$ lb. of endrin per acre) giving 50 per cent control of cutworm and the highest rate (2 lb. of endrin per acre) giving 100 per cent control. Diazinon gave very little control at low rates of application and only 25 per cent at the 2 lb. per acre rate. PP175, a proprietary aphicide, gave no control of cutworm.

CARROT-WILLOW APHID (J. A. Dunn)

Studies were continued on the biology of the carrot-willow aphid and on its seasonal occurrence on various host plants. During the autumn of 1959 winged forms were found on certain species of late-flowering, wild Umbelliferae but regular examinations of willows at several sites in South Warwickshire and Worcestershire showed that very few of the aphids reached their winter hosts. Only small numbers of eggs were found on willows during the winter of 1959-60 and samples of shoots taken from various species of *Salix* showed, as in the previous winter, that most of the eggs were present on *S. fragilis* and *S. alba* and relatively few on *S. caprea*, and *S. atrocinerea*, thus indicating a host preference towards the two first-named species of *Salix*.

In the spring of 1960, because of the scarcity of winter eggs, very small aphid populations developed on willows and the subsequent attack on carrots at Wellesbourne was extremely low. The pattern of immigration was studied on three successive sowings of carrots and daily counts were made of the numbers of winged aphids coming into each plot. The results, which confirmed those of 1959, showed that the immigration peak occurred between 30th May and 2nd June and that there was no

further migration of the aphid to carrots after the first week of July. It was also found that, coincident with the migration to carrots in May, migration took place from willows to other willows, which were again colonised.

A field experiment was carried out to compare the level of aphid control given by certain systemic insecticides, and also to determine the best time for making the insecticide application, but the incidence of carrot-willow aphid on the plots was too low to obtain significant results.

Host preference experiments were carried out in the glasshouse using winged aphids collected from field carrots. The aphids had just migrated from willows, and when transferred to various known hosts they showed a preference for carrots, which they colonised more rapidly than other Umbelliferae, and formed only very weak colonies on willows.

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PLANT PATHOLOGY REPORT

By W. G. KEYWORTH

SILVERING DISEASE OF RED BEET (W. G. Keyworth and J. Sheila Howell)

Observations were continued on commercial seed crops of the variety Cheltenham Green Top grown from seed that had been treated with streptomycin, and which was known in general to be initially infected. On most farms the treatment did not eliminate the disease completely but reduced its incidence to one per cent or less. A paper embodying the results of several years' research on the disease was prepared for publication (2).

CROOK ROOT OF WATERCRESS (J. A. Tomlinson and Bridget R. Smith)

Further experiments on the control of the disease were made in 1959-60 (i) by treating beds with zinc frit and (ii) by treating the water supplying the beds with zinc sulphate.

(i) *Zinc frit*

As previously reported (5) zinc frit applied at $\frac{1}{2}$ lb. or 1 lb. per sq. yd. gave disease control but caused yellowing of the plants in some beds, especially if it was used in successive seasons. Tests were made, therefore, with a new zinc frit which was more finely ground and which also contained more zinc (36 per cent zinc oxide) than that used previously, to determine whether it would be effective if applied at lower rates and at the top (inflow) end of the bed.

In several commercial beds from 130-150 yd. in length the frit gave good control over a five-month period throughout the beds when applied at the rate of 5 oz. per sq. yd. to the top 25 yd. Although there was some initial stunting of the plants (in the treated area only) the treatment seemed likely to be of considerable practical value. Further trials are in progress on the effects of successive applications and on the possibility of still further reducing the quantities applied.

(ii) *Zinc sulphate*

A commercial trial was made at Wilsthorpe, Lincolnshire, in which a solution of zinc sulphate was continuously drip-fed into a large artesian water supply. The treated water contained 0.1 p.p.m. of zinc before being fed into a group of several watercress beds. An adjacent second group of beds fed by untreated water from another source served as a control.

At the beginning of the experiment in January 1960, the amount of crook root infection of plants in all the beds was 50-60 per cent. Crook root infection in the treated beds was reduced to 1-2 per cent in six weeks and was eradicated in eight weeks, whereas in the control beds 55-70 per cent root infection of the plants remained.

The method shows considerable promise for the treatment of beds fed from a single or few water sources. Further trials in collaboration with the N.A.A.S. are now in progress at other farms with the objects of testing the method more extensively and of developing standard drip-feed equipment.

DIDYMELLA STEM ROT OF OUTDOOR TOMATOES (R. B. Maude)

Further studies were made in 1960 on the role of infected seed in the establishment of outbreaks of the disease in the field. Although previous experiments at the Research Station had failed to show that such seed transmission occurred (3), it was still considered a possible method of plant infection. Shortly before the present work was started, Derbyshire (1) had, in fact, demonstrated large amounts of disease in tomato plants grown in the glasshouse from infected seed.

Seed harvested from diseased fruit and selected for heavy infection was used in the trials. Serial sowings were made in January, March and April. A small proportion of the plants raised from the January sowing showed symptoms in the field and it was clear that under some circumstances field infection could arise from infected seed. The seedlings were infected either through the tips of the cotyledons or on the hypocotyl in the region of the upper lateral rootlets and, even in mature plants, it was possible to distinguish those which had contracted the disease from their seed and those which had become infected from external sources. The work is being published in more detail elsewhere.

In collaboration with the Plant Breeding Section the testing of progeny from crosses between *Lycopersicon hirsutum* and *L. esculentum* and of the first and second backcrosses to *L. esculentum*, has been continued.

PARSNIP CANKER (A. G. Channon)

A special study was made in 1959-60 of the importance of parsnip leaf infection by the canker-causing isolate of *Itersonilia*. Whereas in 1958 spores of the fungus were obtained from the air within the crop from July onwards, trappings on exposed Petri dishes in 1959 were not found to be successful until November. This was probably due to the dry season which also caused marked reductions in the amount of canker on the roots.

Parsnips bearing leaves artificially infected with *Itersonilia* were placed, at fortnightly intervals during August-November, within field plots of parsnips grown in sterilised compost. The number of cankered roots was not increased by the presence of plants with infected foliage but there was some evidence of an increase in lesion size.

The plots laid down in 1958 in which diseased and healthy parsnip root tissue had been mixed with the soil, were re-sown with parsnips in 1959 as also were plots of untreated soil. As in 1958, both treatments brought about a similar amount of canker which was greater than that shown by the roots grown in untreated soil.

Pathogenicity tests in the laboratory showed that an *Itersonilia* sp. causing a disease of chrysanthemum florets would not infect parsnip roots or leaves, and the canker pathogen would not infect chrysanthemums.

Further trials of parsnips resistant to both black and orange-brown canker were made in collaboration with the Plant Breeding Section.

CLUBROOT OF SUMMER CABBAGE (A. G. Channon)

Further tests at Luddington E.H.S. were made in 1960 of root dips using suspensions of calomel and aldrin. At the final harvest, approximately ten weeks after planting out, 10 per cent and 2 per cent calomel gave marked reductions in disease. Moderate control was recorded with 0.4 per cent and 0.08 per cent calomel. No increase in disease control was obtained by the incorporation into the calomel suspensions of aldrin with or without a sticker, but the use of aldrin alone with the sticker gave a slight reduction in clubroot. In spite of the marked differences in disease between some of the treatment and control plots, no great difference in the mean weight of either the tops or the marketable hearts was recorded. This was probably due to the fact that the clubroot index on the control plots was less than 3.3 (below which level the disease does not markedly affect the top weight) and also to the abnormally wet weather during the growth of the crop.

In collaboration with the Plant Breeding Section a further trial at Luddington E.H.S. was made of cabbage selections from seed provided by Dr. J. C. Walker, University of Wisconsin. Some of the selections had shown high resistance in 1959. With the exception of one line, which continued to show high resistance, all the selections were more heavily infected than in the previous year, and most were little better than the susceptible varieties. Selections of clubroot-free or only slightly infected plants were taken to Wellesbourne for seed production.

LEAF AND POD SPOT OF PEAS (R. B. Maude)

Tests of possible methods of seed treatment to eliminate the pathogen *Mycosphaerella pinodes* were continued in 1960. In 1959 it was found that soaking heavily infected seed of the variety Kelvedon Wonder for 24 hours in a one per cent suspension of captan at room temperature would greatly reduce infection (4). Further tests showed that after similar soakings at 30°C. no infection was visible on the seed after incubation for nine days, and the treatment caused no loss in viability of the seed.

A number of other fungicides have been tested using the same technique. Thiram, maneb, 'Manam', 'Spergon' and 'Phygon', showed increased fungicidal activity with increase in temperature, thus paralleling captan. All except 'Phygon' gave eradication of disease but apart from thiram they were strongly toxic to seedling development. The effects of the various treatments on subsequent plant growth are now being studied.

BIG VEIN DISEASE OF LETTUCE (J. A. Tomlinson and Bridget R. Smith)

In studies on the *Olpidium* fungus found in the roots of lettuce plants affected with big vein, suspensions of zoospores of the fungus were watered on to sterile compost in which lettuce and cabbage seedlings were growing. The roots of the lettuces became invaded by the fungus and the plants developed symptoms of big vein four weeks later. The cabbage roots on the other hand were not parasitised, thus confirming previous results (6) which indicated that the strain of *Olpidium* in lettuce affected by big vein is pathogenically different from *O. brassicae*. In the course of these trials the roots of a few of the uninoculated control plants became infected by an *Olpidium* but the plants did not show big vein symptoms. Studies of this strain and of others obtained from apparently healthy lettuce are in progress to determine whether they can infect lettuce without inducing symptoms.

In tests of fungicides the disease was controlled by the admixture with infected soil of 0.05 per cent by weight PCNB but was only partially controlled at half this rate. Infection was also eliminated by saturating the soil with 0.5 per cent formaldehyde. Both techniques may be of value in glasshouses and are being further studied for this purpose. They seem unlikely to be economic for field treatment, however.

LETTUCE MOSAIC DISEASE (J. A. Tomlinson and Bridget R. Smith)

The importance of seed-borne mosaic virus infection in the spread of the disease was again studied in summer lettuce trials in different parts of the country. Tests were made using seed of which less than 0.1 per cent was infected and plots were drilled in May 1960 (i) in isolation from other lettuce and (ii) adjacent to other lettuce grown from commercial samples containing 1-3 per cent of infected seeds.

The lettuce in isolated plots remained substantially free from the disease, whereas the lettuce rapidly became infected in plots grown from 1-3 per cent infected seed and also in the adjacent plots grown from seed having less than 0.1 per cent infection, thus confirming the results obtained in 1959 (7).

Following the serious outbreaks of mosaic in 1959-60 in the late summer and winter field crops near Evesham and elsewhere, tests were made to determine the identity of the viruses present. Lettuce mosaic virus and cucumber mosaic virus were repeatedly isolated and many plants were infected with both viruses. In addition, a third lettuce infecting virus was occasionally isolated from plants from a number of farms over a wide area; so far, tests have shown that this virus infects lettuce without causing symptoms and its identity and importance are being studied.

POWDERY MILDEW DISEASES (M. J. W. Webb and J. A. Tomlinson)

Studies have continued on the mechanism of resistance to *Erysiphe polygoni* shown by the leaves of turnip plants when grown in soil watered with solutions of zinc sulphate (500 p.p.m.). When discs were cut from such plants and impregnated in a

solution of ethylene diamine tetra-acetic acid the resistance was removed. Tests have now shown that other chelating agents such as sodium diethyl dithiocarbamate have a similar effect.

Leaf homogenates from zinc-treated turnip plants were fractionated by centrifugation and the supernatants and re-suspended residues were analysed for zinc. Similar amounts of zinc were found in all fractions but no fraction conferred resistance when it was used to impregnate turnip leaf discs.

Resistance to infection by *E. polygoni* occurred in the following cruciferous plants when they were watered with zinc sulphate solution:— *Sinapis arvensis*, *Thlaspi arvense*, *Capsella bursa-pastoris*, *Raphanus raphanistrum*, *Alliaria petiolata*, swede, Brussels sprouts and chinese cabbage. Peas watered with zinc sulphate solutions, however, remained as susceptible to a strain of *E. polygoni* as the untreated controls, despite the large accumulation of zinc in their leaves.

An examination of the structure of turnip leaves has failed to show any changes as a result of zinc sulphate treatments. Studies on the uptake of zinc by powdery mildew spores have now started.

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THE CONTROL OF DAMPING-OFF AND WIRESTEM OF BRASSICA SEEDLINGS CAUSED BY *RHIZOCTONIA SOLANI* KUHN

By W. G. KEYWORTH and JUDITH M. DOW

Brassica seedlings raised in frames before planting out are occasionally attacked by *Rhizoctonia* (*Corticium*) *solani* which causes damping-off or 'wirestem' disease. Watering the soil with a 1:2000 solution of mercuric chloride, either before sowing or at the first 'rough-leaf' stage gives fair control of the disease (2) but this treatment sometimes checks the plants. The material is also highly poisonous. Experiments by Smieton and Brown (3) and Last (1) on *Rhizoctonia* damping-off of lettuce seedlings, demonstrated that pentachloronitrobenzene (PCNB, Quintozene) gave good control when incorporated with the soil, and tests were therefore made at Wellesbourne during 1958-60 to determine whether this treatment would give a practical control of wirestem disease of brassicas.

Two types of trial were made: (a) in pots, using either naturally infested frame soil or artificially infested compost, and (b) in frames in which the disease had occurred previously.

Cabbage, variety Primo, was used in most of the experiments. The PCNB was added to the soil either by incorporating 'Botrilex' (a 20 per cent proprietary powder) or by watering on suspensions made with a 75 per cent wettable powder formulation. The rate found by Last to be effective (0.063 per cent by weight of the 20 per cent dust) was used as a basic treatment.

Experiments in pots

Using naturally infested frame soil

In a series of preliminary trials, 20 per cent PCNB was mixed with the soil in pots at either 0.063 or 0.125 per cent by weight before the seeds were sown. These rates are approximately equivalent to $\frac{1}{4}$ and $1\frac{1}{2}$ oz. per bushel of soil. 30-35 per cent of the seedlings growing in untreated soil became infected within three weeks but none of those in the treated soil was diseased. Mixing the PCNB with only the top inch of soil gave as good control as incorporation of the compound with all the soil in the pot and it thus appeared likely that a shallow treatment of the soil in frames might be effective.

As there were considerable variations in disease from pot to pot a further series of pot tests was made, using J.I. potting compost that had been uniformly infested.

Using artificially infested compost

Light infestation of potting compost, resulting in post-emergence damping-off of the seedlings similar to that seen in the frame soil, was obtained by watering the compost with macerated mycelium of a culture of *Rhizoctonia* (isolated from an infected cabbage seedling) and then mixing the soil well and keeping it in a bin for a week before use. Soil which had been inoculated in this way was used in experiments similar to those described above. 20 per cent PCNB dust mixed either with the whole soil or the top one or two inches gave complete suppression of the disease (controls were 40-50 per cent infected).

In further experiments solid inoculum was used and gave much heavier infection resulting in considerable pre-emergence damping-off. In one such test the fungus was grown on a sand-oatmeal mixture for six weeks and this inoculum was then mixed

with potting compost at the rates of 0.7, 1.4, 2.8 and 5.6 per cent by weight. 20 per cent PCNB dust was also mixed with half of each lot of soil at the rate of 0.125 per cent by weight. Four pots were filled with each of the eight lots of treated compost and each pot was sown with 50 seeds. Four pots of untreated compost were also sown. The results are shown in Table I.

TABLE I
Effect of PCNB in heavily infested potting soil

Concentration of inoculum (%)	Without PCNB		With PCNB	
	Number of seedlings germinated	Number remaining uninfected during growth	Number of seedlings germinated	Number remaining uninfected during growth
0 (control) ...	168	164	—	—
0.7 ...	7	3	161	157
1.4 ...	3	1	153	141
2.8 ...	6	5	162	151
5.6 ...	5	4	73	71

As shown in Table I, 168 of the 200 seeds sown in uninoculated soil germinated and grew, but in all the inoculated pots which had received no PCNB treatment germination was almost completely suppressed, presumably by the attack of *Rhizoctonia* before the seedlings had emerged through the soil. In similar inoculated pots, however, in which PCNB had been mixed with the soil, germination was normal, except with the heaviest inoculation. Most of the seedlings also remained healthy after emergence although the PCNB treatment did not entirely eliminate infection. The experiment illustrates the very considerable effect of PCNB on *Rhizoctonia* even at high inoculum levels.

Experiments in frames

Following the success of the pot tests, experiments were made under commercial conditions in frames where the disease had occurred previously. By weighing known volumes of frame soil it was found that a concentration of the 20 per cent PCNB dust similar to the basic one used in the pot tests (0.063 per cent by weight) would be obtained if $\frac{1}{2}$ oz. of the compound was scattered over each sq. yd. and mixed with the top inch of soil.

Experiment No. 1. A double span frame was prepared for sowing and divided into 36 plots, each of $2\frac{1}{2}$ sq. yd. There were six treatments, shown in Table II, laid out in six randomised blocks. On 11th May the PCNB dust was applied evenly over the appropriate plots and then raked into the top inch of soil. The wettable powder suspensions were watered on evenly and one gallon of water per sq. yd. was also applied to the plots not receiving the suspensions, so that all the plots received the same amount of water. On 15th May five rows of Primo cabbage, eight inches apart, were sown across the central portion of each plot. The occurrence of *Rhizoctonia* infection in two rows in each plot was recorded on 5th June and the results are shown in Table II.

TABLE II
Effect of PCNB on Rhizoctonia infection of cabbage seedlings

No.	Treatment (per sq. yd.)	Number of plants recorded	% infection
1	$\frac{1}{2}$ oz. 20% PCNB dust	1,115	1.9
2	$\frac{1}{2}$ oz. 20% PCNB dust	1,027	2.0
3	2/15 oz. 75% PCNB in 1 gall. water ...	1,455	5.6
4	4/15 oz. 75% PCNB in 1 gall. water ...	1,521	3.3
5	Nil (control)	906	52.4
6	Nil (control)	997	42.0

It is clear from these results that all the PCNB treatments greatly reduced infection. The dust applications were more successful than the watering on of the wettable powder suspensions—possibly owing to the adsorption of the latter on the soil surface.

In a similar experiment made in other frames the treatments were applied eight weeks before sowing. Disease incidence in the untreated plots (16.7 per cent) was less than in Exp. No. 1 but the treatments reduced infection to 0.3-1.1 per cent and it was apparent that their effect had persisted in the soil for eight weeks.

Experiment No. 2. This experiment provided a comparison between treatment with PCNB and with mercuric chloride. There were six treatments replicated three times in randomised blocks. On 14th July the treatments shown in Table III were applied to plots $2\frac{1}{2} \times 2\frac{1}{2}$ yd. One gallon of water per sq. yd. was watered on to each of the plots receiving treatments 1, 2, 5 and 6 and the plots were sown on 17th July. Records of the numbers of infected plants in two rows in each plot made on 7th August are given in Table III.

TABLE III

*Comparison of PCNB and mercuric chloride for control
of Rhizoctonia infection of cabbage seedlings*

No.	Treatment (per sq. yd.)	Number of plants	% infection
1	$\frac{1}{2}$ oz. 20% PCNB dust	386	1.0
2	1 oz. 20% PCNB dust	406	0
3	1 gall. 1/4000 mercuric chloride ...	487	5.7
4	1 gall. 1/2000 mercuric chloride ...	428	1.4
5	Nil (control)	371	14.8
6	Nil (control)	386	14.5

Infection was low in the untreated plots but was greatly reduced by the PCNB treatments which were at least as effective as those using mercuric chloride.

Phytotoxicity tests

In none of the experiments described did the PCNB treatments have an adverse effect on any of the seedlings but it was considered advisable to test whether higher doses would damage the seedlings, especially of plants, e.g., cauliflower, that might be more sensitive than cabbage. Such tests were also made at low temperatures in case damage might occur which was not apparent in warmer conditions.

Two tests were made. In one, conducted in a warm and a cool glasshouse in September, 20 per cent PCNB was mixed with potting compost at rates varying from 0.125 to 2.0 per cent by weight (approx. equivalent to 1-16 oz. per sq. yd.) and cauliflower seeds, variety Finney's 110, were sown in the soil. The seedlings grew well in all the pots and suffered no markedly adverse effects.

The second test was made in February, also in pots, one set being kept in the glasshouse and the other in frames. The glasshouse temperatures varied from 52-85°F. while those in the frame varied from 26-71°F. The soils contained 0.175 to 1.4 per cent of the 20 per cent dust. Cauliflower seeds, variety Record, were sown immediately after the soils had been treated and final records of the germination and average weight, made four weeks later, are given in Table IV.

TABLE IV

Test of the effect on cauliflower seedlings of PCNB mixed with the soil

Treatment (gm. 20% PCNB per 100 gm. soil)	Glasshouse test		Frame test	
	% germination	Average weight of 10 seedlings (gm.)	% germination	Average weight of 10 seedlings (gm.)
Nil	76.5	2.55	55.5	0.47
Nil*	86.0	2.88	74.5	0.44
.175	84.5	2.10	74.0	0.42
.35	69.0	2.19	64.0	0.45
.70	76.0	2.15	77.0	0.34
1.4	73.0	2.09	67.5	0.39

*Soil mixed with 1.4 per cent talc (used as filler in PCNB dust).

None of the treatments caused any seriously adverse effect on the seedlings but, in the glasshouse, germination in all the pots treated with PCNB was delayed 1-2 days and the cotyledons of the young seedlings were darker green than those of the control plants. In addition, the treated seedlings were smaller than the controls. The loss in weight, although small, was significant, but was no greater in the pots receiving the heaviest dose of PCNB than in those with the smallest dose. It seemed unlikely to be of practical importance.

In all the pots kept in the frames at lower temperatures the seedlings germinated much later than those in the glasshouse and thus they were quite small when recorded. There was no evidence that the PCNB had caused any severe damage at any concentration.

The phytotoxicity tests showed that, even at rates vastly exceeding those likely to be applied in practice, the treatment of the soil with PCNB had little effect on cauliflower seedlings at widely differing temperatures. No trials have been made in which the plants were grown to maturity but subsequent experience at Wellesbourne indicates that normal treatments are unlikely to cause damage at any stage of growth.

Conclusions

The experiments described show that in numerous tests PCNB gave good control of *Rhizoctonia* infection of brassica seedlings if the compound was mixed with the soil before the seed was sown. No tests were made on checking the spread of the disease after it had appeared but it is possible that wettable powder suspensions might be of value for this purpose. If outbreaks of wirestem are likely, however, it would seem advisable to mix PCNB with the soil as a precautionary measure, before sowing the seed. Suitable rates of application of the 20 per cent powder are 1 oz. per sq. yd. raked into the top inch of frame soil or 1½ oz. mixed very thoroughly with each bushel of compost used for the germination or potting on of brassica seedlings.

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WEED INVESTIGATIONS

By H. A. ROBERTS

ECOLOGY (Sheelagh M. S. Hird and H. A. Roberts)

Estimations of the numbers of viable weed seeds present in the soil of plots of the cultivation experiment (1) were continued. During the first four years of vegetable cropping, there was a progressive reduction in the overall population to a level only 8 per cent of that originally present. In the wet summer of 1958, however, it proved impossible to obtain adequate control of weeds and some were able to mature and set seed. The results from samples taken in autumn 1958, at the end of the fifth year of cropping, showed that the total number of weed seeds in the soil had become more than twice as great as that recorded in the previous year. No increase was found in seeds of orache (*Atriplex patula*), fumitory (*Fumaria officinalis*) or wild radish (*Raphanus raphanistrum*), but there were considerable increases in the numbers of seeds of annual meadow grass (*Poa annua*), chickweed (*Stellaria media*) and shepherd's purse (*Capsella bursa-pastoris*). The increase in seed numbers of these and of certain other species was especially marked on plots which had received rotary cultivation.

Soil samples were taken from the plots of all three long-term experiments (1) in autumn 1959, at the end of the second three-year cycle of the rotation. Samples were also taken from plots of the cultivation experiments sponsored by the N.I.A.E. at Efford, Luddington and Stockbridge House E.H.S. to determine the weed seed populations at the end of six years of cropping. In addition, a survey has been started to obtain information on the numbers and kinds of weed seeds present in the soil of commercial holdings on which vegetables have been grown for a period of years.

Studies were continued with certain species to determine the period required from anthesis to ripe seed production and to compare the germination behaviour of seeds at different stages of maturity. The germination of groundsel (*Senecio vulgaris*) was found to be affected both by the stage of maturity and the time of the year at which the seed was produced. It appeared that variations in environmental conditions at the time of seed production affected the germination of fully ripe seed to a greater extent than that of immature seed. Further observations were made on the comparative biology of mayweeds (*Matricaria* spp.).

CHEMICAL CONTROL (H. A. Roberts and B. J. Wilson)

Experiments on the use of dinoseb-amine as a residual pre-emergence herbicide for use in runner and French beans were concluded, and the results written up for publication. This method of weed control gave good results in commercial practice during 1959 and 1960. Trials with simazine for residual control of annual weeds in established asparagus beds were also concluded, having shown that simazine is a satisfactory alternative to monuron for this purpose.

Further field experiments with substituted triazine herbicides related to simazine confirmed the indications obtained in 1959 (2, 3). Pre-emergence application of propazine at $\frac{1}{2}$ lb. per acre gave good weed control in carrots and parsnips without adverse effect on yield, while pre-emergence treatment with 1-2 lb. per acre of trietazine showed promise in peas, broad beans, French beans and in spring-sown field beans. In an experiment on sweet corn, atrazine applied as a post-emergence spray gave excellent results, comparable with those obtained from pre-emergence treatment with simazine. Further work with amiben (3-amino-2, 5-dichlorobenzoic acid) also confirmed the results obtained in 1959 (2). During the dry spring of 1960, pre-emergence applications at rates of from 2-4 lb. per acre appeared promising in carrots, parsnips and in large-seeded legumes, but further testing under conditions of higher rainfall is

required before conclusions can be drawn regarding crop safety. The possible use of granular formulations of amiben in transplanted crops was also examined.

Preliminary tests were carried out with three new selective post-emergence herbicides from the U.S.A. at present known only under trade names:

'Karsil' — N-(3, 4-dichlorophenyl)-2-methylpentanamide

'Solan' — N-(3-chloro-2-methylphenyl)-2-methylpentanamide

'Dicryl' — N-(3, 4-dichlorophenyl) methacrylamide

It was found that at rates of 2-4 lb. per acre, applied at various stages of growth, weeds which were readily killed included fumitory (*F. officinalis* and *F. micrantha*), pennycress (*Thlaspi arvense*), fat hen (*Chenopodium album*), orache, annual nettle (*Urtica urens*), shepherd's purse and black bindweed (*Polygonum convolvulus*). Groundsel and the mayweeds (*Matricaria chamomilla* and *M. maritima* ssp. *inodora*) were more tolerant, and were only killed when sprayed at the seedling stage. There were some interesting differences in the response of weed species to individual compounds. Buxbaum's speedwell (*Veronica persica*), for example, was much more resistant to 'Dicryl' than to 'Solan' or 'Karsil', while cranesbill (*Geranium pusillum*) appeared relatively tolerant to 'Solan'. The three materials were tested primarily as selective herbicides in crops of carrots, parsnips and parsley, all of which showed marked tolerance. Further work is planned to determine the optimum application rate and the stage of growth at which best results can be obtained.

Tests were conducted with peas, beans and onions to compare the phytotoxicity of chlorpropham (CIPC) and mixtures of chlorpropham with either fenuron or diuron. In some of the experiments, it was quite clear that significant crop injury was caused by the chlorpropham in the mixtures, whereas in others, there was no evidence of any injury attributable to chlorpropham, but damage of the kind typical of fenuron and diuron was observed. In such instances, greater injury resulted from treatment with fenuron than from treatment with diuron, a finding consistent with the known greater mobility of fenuron in the soil. Other herbicides examined in field experiments included a proprietary formulation of BiPC (butinol-N-(3-chlorophenyl) carbamate) and OMU (N-cyclooctyl-N'-N'-dimethylurea), which gave good results in carrots, parsnips and several other crops. Excellent control of annual nettle, fat hen, shepherd's purse and several other weeds was achieved, but fumitory was not affected. Adequate soil moisture was found to be necessary in order to obtain good weed control. In an experiment on weed control in Dutch light frames, allyl alcohol applied as a drench before sowing or planting gave promising results.

Further work has been carried out on the persistence in the field of substituted urea and triazine herbicides, using the bioassay method previously mentioned (2). During the dry season of 1959, disappearance of these materials in undisturbed soil was very slow. The presence of monuron could still be detected 32 weeks after an application of $\frac{1}{2}$ lb. per acre in April 1959, while on plots treated with 2 lb. per acre, it could be detected 54 weeks after application. In 1960, disappearance was more rapid and following application of $\frac{1}{2}$ lb. per acre, nothing could be detected after a period of 16 weeks. A bioassay method for chlorpropham in soil has been developed, using primary root extension of buckwheat, which will detect amounts of less 0.08 lb. per acre mixed with 2 inches of soil. This is being used to study the disappearance of chlorpropham from field plots under different conditions.

SPRAY DRIFT (J. M. Way)

Investigations into the effects of low dose rates of growth-regulator herbicides on the morphology, yield and marketability of a range of vegetable crops were continued.

In field experiments during the past three seasons, MCPA-sodium was applied to 12 vegetable crops at dose rates ranging from 0.003 lb. per acre up to the normal agricultural rate of 1-2 lb. per acre (acid equivalent). The lowest rates at which economically important losses of marketable yield occurred were as follows:—

0.01	— 0.025 lb. per acre	— lettuce, carrot, turnip
0.025	— 0.05 lb. per acre	— parsnip, spinach, cauliflower, cabbage
0.05	— 0.1 lb. per acre	— red beet
0.1	— 0.25 lb. per acre	— French bean, Brussels sprout
0.25	— 0.5 lb. per acre	— broad bean
>0.5	lb. per acre	— onion

In some crops, the above dose rates reduced the actual weight of produce, in others, the weight was not reduced but the presence of abnormalities rendered a portion of the yield unmarketable. Formative responses, including thickening of stems and the production of adventitious roots and abnormal leaves, occurred at lower dose rates without affecting marketability. Initial epinastic responses (downward bending of leaves, and sometimes curling of stems and petioles) also occurred at lower dose rates and appeared within 6–24 hours of treatment. In carrot and lettuce, clearly discernible epinasty was induced by treatment with 0.003 lb. per acre.

In several field and glasshouse experiments, crops were treated with MCPA at different stages of growth. In general, it appeared that small plants were more readily killed by the higher dose rates employed than were plants sprayed at later stages of growth. At sub-lethal dose rates, however, plants treated at an early stage produced higher marketable yields than those treated with the same rates later on. In lettuce, for example, treatment at an advanced stage of growth affected the leaves immediately round the hearts, rendering the plants unmarketable, whereas in plants sprayed at an early stage, formative effects were limited to the lower leaves and the hearts were unaffected. In French bean, treatment at the unifoliate leaf stage with a sub-lethal dose of MCPA resulted in little or no delay in crop maturity; treatment at the third trifoliate leaf stage delayed maturity by some three weeks. The experiments as a whole suggest that greatest loss of marketable yield is likely to occur when treatment is carried out when the organs comprising the economically important part of the plant are in a state of rapid growth or expansion.

A series of experiments was conducted in which the effects of MCPA, 2,4-D, 2,4,5-T, mecoprop (CMPP) and 2,3,6-TBA were compared on vegetable crops. In general, the effects induced by the first four were similar, although the order of severity of the compounds varied according to the crop. 2,3,6-TBA, however, had little effect on most crops, but in spinach, red beet, broad bean and French bean this compound induced marked formative effects which appeared to be characteristic.

In all the experiments, detailed notes have been made on the development of formative responses and typical symptoms illustrated in a collection of some 400 photographs and 250 colour transparencies. Study of these suggests that there is little likelihood of confusing them with abnormalities induced by common pests or diseases, but that difficulty may arise in distinguishing formative effects in certain crops at particular stages of growth from symptoms associated with virus infection or with nutritional or physiological disorders. It seems probable, however, that the *sequence* of symptoms resulting from growth-regulator injury would be sufficiently characteristic to provide adequate distinction, and that the diagnosis of spray drift damage should be based on observation of this sequence, and not on inspection on a single occasion.

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STATISTICS REPORT

By J. A. NELDER

Statistical and mathematical problems arising during the work of the other sections on the Station continued to occupy a good deal of the time of the Section. These included non-routine analyses of various kinds and the construction of models for various biological situations. There was also the usual number of requests for advice on the design and interpretation of experiments. Miss Kemp made a study of the errors involved in estimating the median response time (T50) in time-response assays by eye instead of numerically. A sampling experiment using artificial data showed that the additional error of an eye fitting over a numerical one for the determination of T50's was small and this was confirmed using actual assay data. Compared with the true between-plot sampling error of the field experiments from which the data were derived, errors introduced by fitting by eye were trivial.

Experimental technique

A further experiment was done with red beet to investigate causes of variation in the field, attention being concentrated on the pattern of germination and emergence. The treatments comprised two depths of sowing ($\frac{3}{4}$ and $1\frac{1}{2}$ inches) combined factorially with two types of seed-bed, rough and smooth. In two of the blocks seedlings were marked on emergence with small spots of paint, a different colour being used for each day. The paint was renewed as the plants grew so that at harvest plants could be grouped according to day of emergence. At harvest the mean size of plant within plots showed a striking decline with lateness of emergence. Thus plants that emerged five days after the first seedlings gave roots whose mean diameter was only 60 per cent of those emerging first; the corresponding weight was between a quarter and a fifth. Deeper sowing slightly delayed the mean germination time as did the rough seed-bed when compared with the smooth, but the joint effect was barely half a day. However, the joint effect of the two factors on marketable yield at harvest was 16 ± 4 per cent, despite the slightness of the treatments' effect on germination time, and this joint effect was not mainly attributable to the equally slight differences in stand. The treatments had no appreciable effect on the variability of the root sizes within plots or on the variability of yield between plots of the same treatment. Thus the experiment showed that while plant-to-plant variability may be considerably the result of early differences in germination time, cultural treatments imposed with the aim of improving the uniformity of conditions for germination failed to produce the looked-for reduction in this variability, even though they succeeded in improving the marketable yield.

Systematic designs for spacing experiments

Spacing experiments in which the spatial arrangement of the plants is kept constant while the density is changed are awkward to lay out in the standard randomised way because of differences in plot size, and are relatively inefficient in the use of land and materials because of the high proportion of guard plants necessary. Experience with vegetable crops at Wellesbourne has shown that, with care in choice of site, the correlations between yields of neighbouring plots are frequently unimportant; hence it becomes reasonable to consider whether systematic designs may have some advantage for spacing experiments in these conditions. Following Dr. Bleasdale's suggestion of using a design in which plants were spaced in effect along the spokes of a wheel, an investigation was made of possible designs based on polar co-ordinates, i.e., using the radii and circumferences of concentric circles. A suitable design must give simple

forms to the contours of equal density and equal shape; designs were devised which would change the area per plant while holding the shape of the area constant and vice versa, also designs which allowed both the area and shape to be varied simultaneously. A suitable design of this last type was also produced for a rectangular grid. These designs should prove useful in investigating the effect of spatial arrangement at different densities. Preliminary tests of the designs in the field have been made for a number of crops and some comments on those are given in the Physiology report.

Growth analysis

A model proposed by Japanese workers (7) for the relation between yield and density in spacing experiments has been examined in detail. In its original form it was found to be unsatisfactory in many cases, but a simple extension of it shows considerable promise in describing the behaviour of a number of crops (2). A further extension to cover the yields of two species growing in competition has been applied to data published by Black (1) and gives a reasonably good fit. Appropriate statistical methods for fitting the non-linear relationships required have been worked out. One of the bases of the yield-density model is the generalised logistic curve described by Richards (6); a method of fitting this curve is described in a paper now in the press (4).

The growth patterns of a simple theoretical 'organism' proposed by Hinshelwood (3) have been shown to be capable of exact description and a note on the subject is now in the press (5).

Work for other bodies

Analyses for the N.A.A.S. fell below last year's peak. Results from 71 experiments involving 4,171 plots were analysed, each analysis involving an average of four variates, rather more than in previous years. J. A. Nelder again served on the Protected Cropping Working Party of the A.I.C.'s Experimental Horticulture Committee and on the N.A.A.S. Vining Pea Group.

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THE WEATHER DURING 1960

RECORDS OF THE N.V.R.S. AGRO-MET. STATION

By CHRISTINE DOWN, E. J. WINTER, and R. B. AUSTIN

The distribution of rainfall during 1960 was similar to that in 1956, 1957 and 1958; a comparatively dry spring was followed by wet conditions for the remainder of the year. The total rainfall recorded in 1960 was 31.54 inches, the highest since records were started at Wellesbourne in 1951. The previous highest was 30.39 inches in 1951. The wet summer and autumn seriously interfered with harvesting and ploughing.

The weather records for 1960 and the winter of 1959-60 are summarised in the tables and graph.

The graph shows that following the abnormally dry 1959 season, the soil was not fully restored to field capacity during the winter of 1959-60. In contrast, in the following winter the soil moisture status reached field capacity before the end of 1960. It should be noted that the graph shows deficits calculated according to the theoretical maximum possible transpiration of a green crop, fully covering the ground and having unlimited water supply; in practice, soil moisture shortage is liable to limit transpiration and thus prevent the accumulation of some of the higher deficits shown.

During 1960 it was suspected that some of the containers of the weighable soil cores used for direct determination of actual evapo-transpiration from grass had developed leaks and figures derived from these instruments for this year have, therefore, been omitted from the tables and graph.

It has been shown previously (1) that rainfall collected at ground level may exceed that collected in the standard gauge with its rim 12 inches above ground. In collaboration with the Meteorological Office an unorthodox raingauge having nine separate square collecting funnels is being used to assess the efficiency of various materials such as wire mesh and plastic slats in preventing insplash into ground level gauges.

Rainfall has been measured at the N.V.R.S. Sub-Station at Paglesham, Essex, during 1960 by Mr. McVittie, and the records were as follows:—

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total inches
1.82	1.11	1.20	0.38	1.95	1.69	2.70	2.95	3.31	5.46	3.19	1.94	27.70

REFERENCE

- (1) STANHILL, G. (1958). Rainfall measurements at ground level. *Weather*, **13**, 33-4.

TABLE I

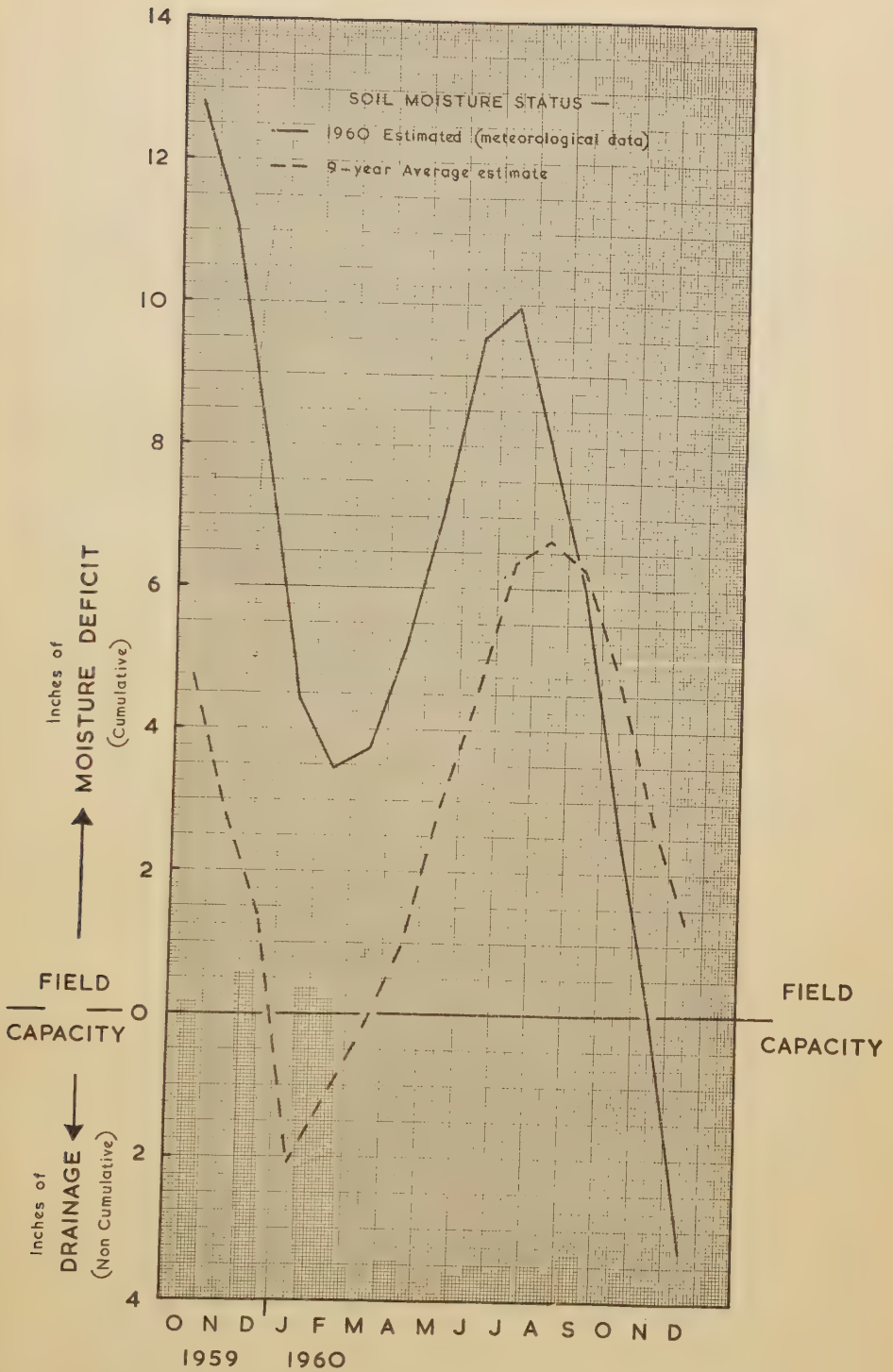
Summary of various weather features during 1960

				*10-year average
Sunshine:	sunniest month	...	June (daily average 8.61 hours)	6.1 hours.
	dullest month	...	January (daily average 0.61 hours)	1.5 hours.
	most in a day	...	15.2 hours on 24th May (94% of possible).	
Rainfall:	wettest month	...	August (4.73 inches)	3.23 inches.
	driest month	...	April (0.65 inches)	1.24 inches.
	most in a day	...	1.62 inches on 31st August	
	total during 1960	...	31.54 inches	24.86 inches.
Wind:	windiest month	...	March (daily average run—162 miles)	145 miles.
	calmest month	...	September (daily average run—85 miles)	109 miles.
	windiest day	...	3rd December (day's run—380 miles)	
	calmest day	...	18th November, 17th December (day's run—14 miles)	
	daily average run of wind during 1960—123 miles.			
Air temperature:				
	warmest month	...	61°F. mean temperature in June 58°F. (9-year average)	
	coldest month	...	38°F. mean temperature in December 40°F. (9-year average)	
	highest maximum	...	84°F. on 18th June.	
During winter 1959-60:				
	lowest minimum	...	19°F. on 14th January 1960, i.e., 13° of frost.	
	first air frost	...	30°F. on 27th September 1959.	
	last air frost	...	27°F. on 30th April 1960.	
	number of nights with air frost—59			69
	number of nights with ground frost—93			102

*The averages refer to the corresponding month or period during the previous ten years. Thus, in the first entry in the table, the average daily number of hours of sunshine for June during the past ten years was 6.1, but June was not necessarily the sunniest month in every year.

TABLE II
Observations made at N.V.R.S. Agro-Met. Station during 1960

Month	Air temperature °F.		Number of frosts		Mean soil temperature °F. at 0900 hr. G.M.T.			Rainfall		Total sun hours	Total solar radiation, gm. calories	Mean daily run of wind, Miles	Evaporation from water surface, Total inches
	Mean Max.	Mean Min.	Air	Ground	4"	12"	48"	Total inches	Number of days with rain				
January	44	35	15	18	37.9	40.2	43.5	3.72	18	18.9	1360	143	0.04
February	44	33	16	20	36.7	38.8	41.9	1.58	16	67.6	3015	153	0.11
March	49	38	3	10	41.5	43.3	43.9	0.91	16	66.5	4831	162	1.16
April	56	38	7	11	47.8	47.7	41.9	0.65	8	140.7	8264	146	2.08
May	64	45	0	2	56.9	55.3	52.0	1.28	7	176.6	11200	101	2.03
June	72	51	0	0	65.5	64.2	59.2	1.99	11	258.3	14135	123	4.82
July	67	52	0	0	62.0	62.5	61.0	3.03	22	151.7	10866	120	3.40
August	67	51	0	0	60.5	62.3	60.9	4.73	18	158.1	9615	88	2.70
September	63	48	0	0	55.5	59.0	59.6	3.48	15	121.6	6123	85	1.63
October	56	44	1	5	49.2	52.3	54.5	4.08	25	53.0	2783	104	0.55
November	51	38	7	12	42.7	45.8	49.3	2.86	25	68.4	1857	135	0.46
December	43	33	15	19	37.6	41.2	45.3	3.23	17	51.9	1087	115	0.11
Total 1960	—	—	64	97	—	—	—	31.54	198	1333.3	—	—	19.01
10-year average ...	—	—	—	—	—	—	—	24.86	172	1395.5	—	—	—



The loss of water by drainage and by evapo-transpiration from a soil fully covered by green crop.

LIBRARY REPORT

By D. A. WOODROFFE

The library was without a full-time librarian from June 1959 until the end of March 1960. Routine work was continued with the help of Mrs. A. H. T. George and Mr. H. A. Roberts, but borrowing from other libraries was reduced to a minimum, and cataloguing of the separates and some other material received was suspended.

Normal library services were resumed in April and between then and the end of September 119 items were borrowed from other libraries and five items were loaned by the N.V.R.S. to other libraries.

During the year 93 complete volumes of journals were bound, and the library now holds 914 bound periodical volumes.

Current periodicals received number 169. The majority of these are obtained by subscription, but a few are obtained in exchange for the N.V.R.S. Annual Report.

In June 1960, a journal holdings list was produced, and copies of this were sent to 13 other libraries, in addition to being available for internal use. Formalities were completed in July to enable the N.V.R.S. library to borrow from the Science Library in London. Previously many journals held by the Science Library were available only after application had been made through the Regional Library Bureau and the National Central Library. Thus there is now a considerable saving in time when borrowing these items.

Sincere thanks are due to Dr. Alexander Nelson for further gifts to the library. These consist of two books by the late Dr. W. Lawrence Balls, the Transactions of the Royal Society of Edinburgh 1930-39, and various separates.

PUBLICATION RECORD

BLEASDALE, J. K. A. (1959). The effects of air pollution on plant growth. *The effects of pollution on living material*. Yapp, W. B. (Editor). London: Institute of Biology. 1959, 81-7.

(A review of the effects of air polluted with coal smoke on the growth of plants).

BLEASDALE, J. K. A. (1960). Gravimorphism and root formation. *Nature, Lond.*, **185**, 544-5.

(Shoots of *Bryophyllum daigremontianum* and tomato, when kept in a horizontal position, formed numerous root primordia on the lower side of the stems).

BLEASDALE, J. K. A. (1960). Studies on plant competition. *The biology of weeds*. Harper, J. L. (Editor). Oxford: Blackwell Scientific Publications. 1960, 133-42.

(A scheme is proposed which evaluates the competition encountered by an individual plant in terms of the density and distribution of its competitors, the species competing and the duration of the competition. Climatic and edaphic conditions are represented as having a modifying effect and examples are given using data on vegetable crops and weeds.

It is concluded that it is reasonable to assume that plants can compete for the supply of nutrients, light or water, either simultaneously or in rapid succession. Plant growth integrates this situation, thus justifying the use of plant weight as an index of competition. This enables competition to be defined and studied in quantitative terms).

BLEASDALE, J. K. A. and ROBERTS, H. A. (1960). The effects of different methods of seed-bed preparation on weed emergence. *Rep. nat. Veg. Res. Sta. Wellesbourne for 1959*, 46-9.

(Field experiments showed that weed numbers increased with increasing fineness of tilth and that there were greater numbers on plots which had been rolled. Some implications of these results are discussed).

CHANNON, A. G. and KEYWORTH, W. G. (1960). Field trials of the effect of aldrin on clubroot of summer cabbage. *Ann. appl. Biol.*, **48**, 1-7.

(Marked reduction in clubroot and increases in yield of Primo cabbage were obtained by applications of commercial aldrin preparations in the field).

DUNN, J. A. (1960). The use of endrin and other insecticides against lettuce root aphid, *Pemphigus bursarius* L. *Ann. appl. Biol.*, **48**, 314-22.

(An endrin seed dressing with supplementary seedling spray consistently gave about 90 per cent control of aphid numbers but, because the levels and persistence of endrin residues on lettuce were unknown, this treatment could not be recommended for practical use. The problem of spray residues on foliage, however, did not arise when a pre-sowing soil treatment of endrin or diazinon was used, and this method appeared to be a much more satisfactory means of controlling the pest).

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(This aphid is gall-inhabiting in spring and lives underground during summer, and hence its natural enemy complex differs from that associated with foliage feeding aphids. Only the fundatrix is attacked by parasites. *Anthocoris nemorum* (L.) and *A. nemoralis* (F.) are the main predators at the gall stage of the aphid. *Thaumatomyia glabra* (Mg.) and *T. notata* (Mg.) are common predators of the aphid in the soil).

- DUNN, J. A. (1960). Varietal resistance of lettuce to attack by the lettuce root aphid, *Pemphigus bursarius* L. *Ann. appl. Biol.*, **48**, 764-70.
(Several varieties of lettuce were found to be highly resistant to attack by the lettuce root aphid. The winged immigrant aphids did not discriminate between plants of different varieties but resistant plants were biologically unsuitable for subsequent colonisation. Root sap analyses have failed to show consistent differences between resistant and susceptible varieties).
- DUNN, J. A. (1960). Black poplars shelter this pest. *Grower*, **53**, 893, 895.
(The salient points of the life cycle of lettuce root aphid and practical husbandry methods aimed at reducing damage by this pest are given. The best practical chemical control is stated and, as an alternative to chemical treatment, it is suggested that one of the listed varieties of lettuce which is resistant to attack should be grown).
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(Male asparagus plants live longer and give a higher yield than females. A technique is described by which seed can be produced that will give an all-male population instead of the normal mixed population).
- HUGHES, R. D. and SALTER, Dorothy D. (1959). Natural mortality of *Erioischia brassicae* (Bouché) (Diptera, Anthomyiidae) during the immature stages of the first generation. *J. Anim. Ecol.*, **28**, 231-41.
(A brief account is given of the biology of the cabbage root fly and methods are described for the enumeration of the populations of the different stages in the life cycle. Five years' records of the population losses occurring during the first generation are summarised and the possible causes of mortality discussed).
- HUGHES, R. D. (1959). The natural mortality of *Erioischia brassicae* (Bouché) (Diptera, Anthomyiidae) during the egg stage of the first generation. *J. Anim. Ecol.*, **28**, 343-57.
(A method of deriving the average survival of cabbage root fly eggs is described. The relationship of predation to the daily catches of ground beetles is used to estimate the probability of egg survival. Results suggest that in the first generation of 1958 and 1959, over 90 per cent of the egg losses is due to predation).
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(A simplified method of estimating the number of cabbage root fly pupae in the soil around brassica plants is described).
- HUGHES, R. D. (1960). Induction of diapause in *Erioischia brassicae* (Bouché) (Diptera, Anthomyiidae). *J. exp. Biol.*, **37**, 218-23.
(The overwintering pupae of the cabbage root fly appear to be in a state of facultative diapause. Diapause induction takes place during the larval development and appears to be governed by changes in the daylength. It is suggested that the stimulus is passed on to the insect by way of a change in the composition of its food).
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(A general survey of the subject, intended to help gardeners).

THE JOURNAL OF HORTICULTURAL SCIENCE

The Journal of Horticultural Science, which is sponsored by the Long Ashton Research Station and the East Malling Research Station, welcomes contributions on horticultural science from Research Institutes at home and abroad. Papers for publication and all communications should be sent to the Editors at East Malling Research Station, Maidstone, Kent.

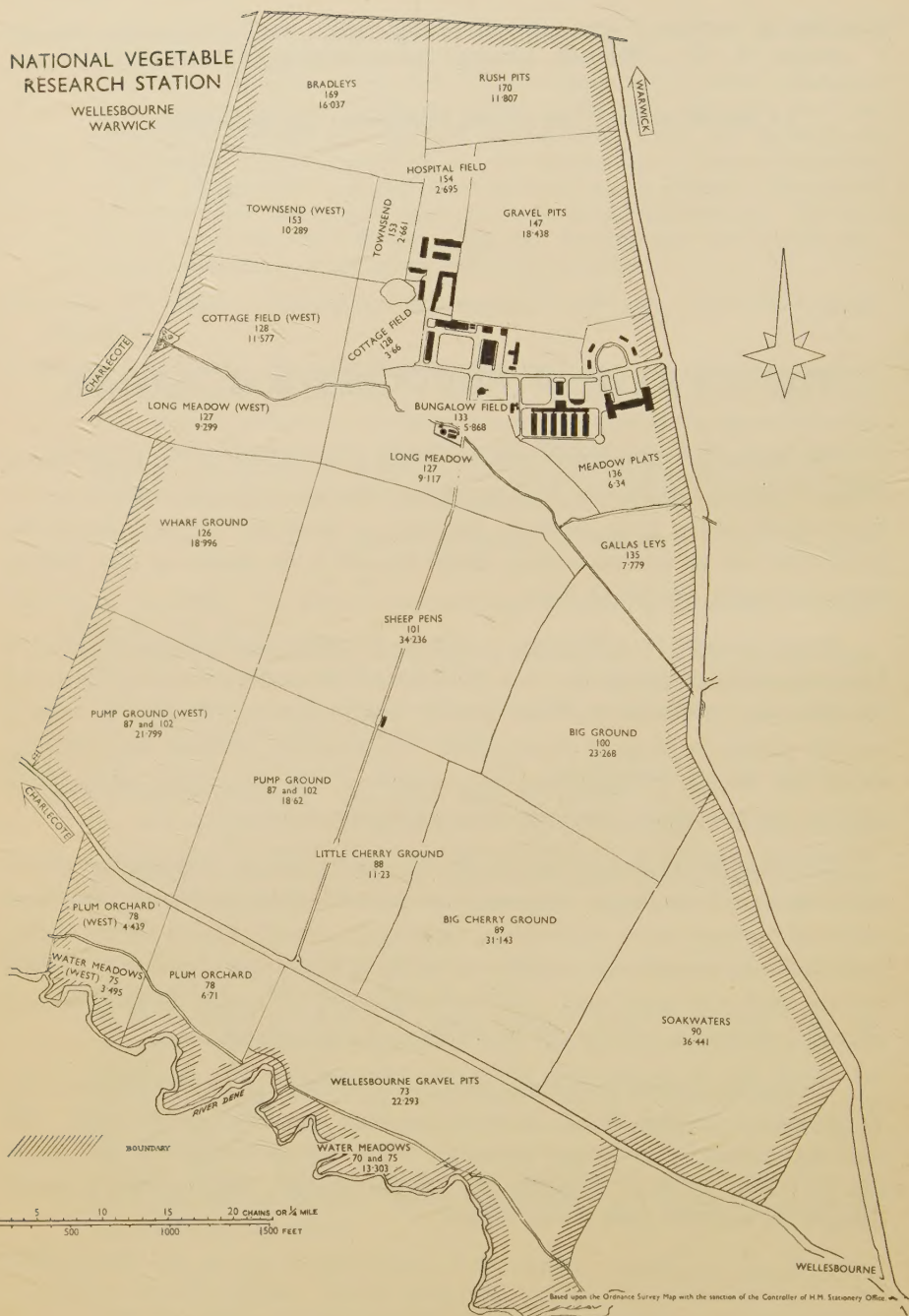
Papers accepted for publication in Volume 35 (1960) and the current Volume 36 have been received from all the main Horticultural Research Institutes in the United Kingdom and, in Volume 36, from Canada, New Zealand and Ghana. In recently received papers the range of crops covered is considerable, including early potatoes, spring and summer cabbage, leeks and cauliflower, and also apples, plums, black currants and raspberries, tomatoes, roses, mushrooms and cocoa.

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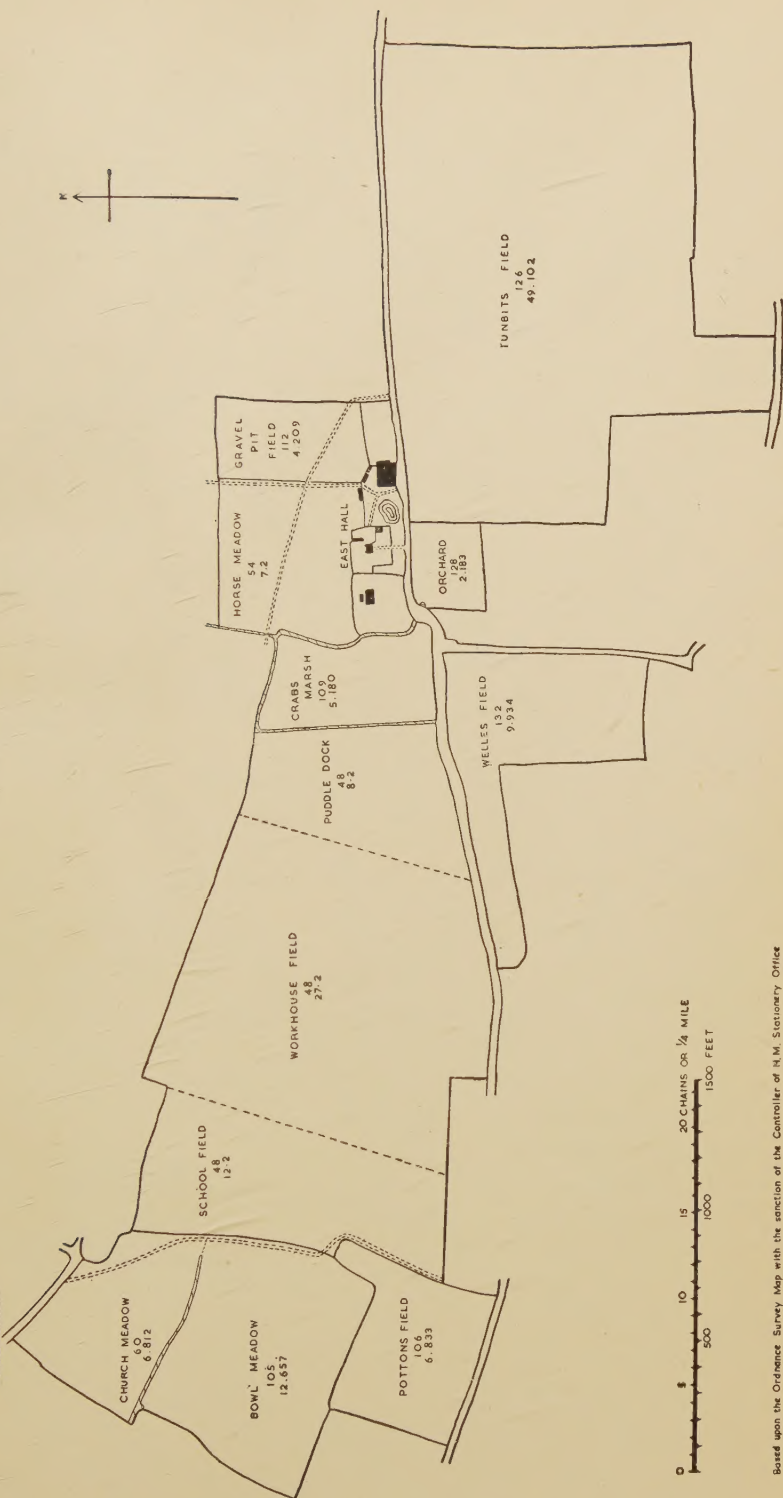
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